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AMERICAN SOCIETY
FOR
TESTING MATERIALS.

AFFILIATED WITH THE
INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

PROCEEDINGS
OF THE
TWELFTH ANNUAL MEETING

Held at Atlantic City, New Jersey,
June 29-July 3, 1909.

VOLUME IX.

EDITED BY THE SECRETARY, UNDER THE DIRECTION OF
THE COMMITTEE ON PUBLICATIONS.

OFFICE OF THE SECRETARY, UNIVERSITY OF PENNSYLVANIA, PHILADELPHIA, PA.
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SUMMARY OF THE PROCEEDINGS OF THE TWELFTH ANNUAL MEETING.

ATLANTIC CITY, N. J., JUNE 29-JULY 3, 1909.

THE TWELFTH ANNUAL MEETING OF THE AMERICAN SOCIETY FOR TESTING MATERIALS was held at the Hotel Traymore, Atlantic City, N. J., on June 29-July 3, 1909. The total attendance at the meeting, including guests, was over 300.

The following members were present or represented at the meeting: Herbert Abraham; W. A. Aiken; Ajax Metal Company, represented by G. H. Clamer; American Asphaltum and Rubber Company, represented by Ray B. Nisbet; American Brass Manufacturing Company, represented by William H. Bassett; American Bridge Company, represented by A. J. Christie; American Foundrymen's Association, represented by Richard Moldenke; American Steel and Wire Company, represented by John F. Tinsley; E. B. Ashby; A. O. Backert; Edwin G. Bailey; Barrett Manufacturing Company, represented by W. S. Babcock; T. J. Bateman; Florus R. Baxter; Laurence L. Beebe; A. W. Belden; H. B. Bent; H. C. Berry; Bethlehem Steel Company, represented by E. O'C. Acker; Robert M. Bird; John Birkinbine; Arthur H. Blanchard; A. V. Bleininger; A. Bonzano; Booth, Garrett and Blair, represented by Robert Job; Cyrus Borgner; W. A. Bostwick; F. C. Bowers; C. W. Boynton; Henry C. Boynton; John G. Brown; D. M. Buck; W. C. Bullitt; F. O. Bunnell, represented by T. D. Sedwick; Jacob Cambier; Cambria Steel Company, represented by George E. Thackray; John A. Capp; Carnegie Steel Company, represented by W. A. Bostwick; F. D. Carney; G. H. Charls; Alexander J. Christie; James Christie; Sumner R. Church; Charles S. Churchill; Albert Ladd Colby; J. Allen Colby; Colorado Fuel and Iron Company, represented by Jacob Cambier; Columbia Steel and Shafting Company, represented by A. A. Kealey; P. H. Conradson; R. D. Coombs; William A. Cooper; W. W. Crosby; Robert A. Cummings; W. C. Cushing; Edgar A. Custer; George C. Davies; Edward W. DeKnight; John

Dewar; R. D. DeWolf; L. C. Dilks; Joseph Dixon Crucible Company, represented by Malcolm MacNaughton; Proctor L. Dougherty; D. E. Douty; Allan W. Dow; Charles B. Dudley; H. O. Duerr; W. O. Dunbar; Hubert Dunning; Warrick R. Edwards; *Engineering Record*, represented by John M. Goodell; Henry Fay; James T. Fennell; Lewis R. Ferguson; Robert H. Fernald; A. I. Findley; Peter Fireman; H. J. Force; C. N. Forrest; Froehling and Robertson, represented by Andrew Robertson; W. Herbert Fulweiler; Richard H. Gaines; Henry A. Gardner; General Electric Company, represented by J. A. Capp; James H. Gibboney; W. S. Godwin; William Gowie; Russell S. Greenman; R. E. Griffith; Samuel Hamburger; G. B. Heckel; George P. Hemstreet; Rudolph Hering; Milton L. Hersey; Raymond W. Hilles; Martin Hokanson; Joseph A. Holmes; James E. Howard; James W. Howard; Henry M. Howe; Prévost Hubbard; Richard L. Humphrey; S. V. Hunnings; Robert W. Hunt Company, represented by Robert W. Hunt; Joseph W. Hunter; Elwood T. Ickes; F. P. Ingalls; *The Iron Trade Review*, represented by A. O. Backert; Fred K. Irvine; John M. Jeffers; Robert Job; Jones and Laughlin Steel Company, represented by J. J. Shuman; E. F. Kenney; J. A. Kinkead; W. M. Kinney; George B. Koch; Paul Kreuzpointner; Lackawanna Steel Company, represented by Franklin E. Abbott; E. A. Langenbach, represented by A. T. Enlow; Gaetano Lanza; E. S. Larned; Thomas R. Lawson; E. W. Lazell; R. W. Lesley; T. A. Leyshon; Harry C. Loudenbeck; Alfred Lovell; John Lucas and Company, represented by F. A. Lane; Lukens Iron and Steel Company, represented by W. H. Hamilton and Charles L. Huston; R. W. Mahon; Edgar Marburg; John W. Masury and Son, represented by F. P. Ingalls; John A. Mathews; E. R. Maurer; E. T. McCleary; Ernest B. McCreedy; Andrew S. McCreath and Son, represented by Andrew S. McCreath and Lesley McCreath; Charles F. McKenna, represented by C. M. E. Schroeder; D. W. McNaugher; Charles A. Mead; Richard K. Meade; Mansfield Merriman; Robert Mitchell; Leon S. Moisseiff; Richard Moldenke; Mace Moulton, Jr.; Albert Moyer; Charles E. Munroe; J. A. Munsell; National Tube Company, represented by Frank N. Speller; A. F. Neal; Thomas Neal, represented by C. S. Neal; E. D. Nelson; George L. Norris; Tinius Olsen; James Owen; Logan Waller Page; W. Marshall Page; The Pennsylva-

nia Steel Company, represented by H. B. Bent and F. D. Carney; R. S. Perry; Pittsburg Testing Laboratory, Limited, represented by James Otis Handy; W. A. Polk; W. A. Powers; *Railroad Age Gazette*, represented by F. E. Lister; *Railway and Engineering Review*, represented by Willard A. Smith; J. C. Ramage; D. T. Randall; Remington Arms Company, represented by Nathan A. Chase; George N. Riley; C. D. Rinald; *Rock Products*, represented by Fred K. Irvine; John A. Roebbling's Sons Company, represented by Henry C. Boynton; Joseph Royal; C. Rys; A. H. Sabin; F. E. Schmitt; Harry J. Seaman; Semet-Solvay Company, represented by W. H. Blauvelt; John M. Sherrerd; Charles Shults; Jesse J. Shuman; C. E. Skinner; Orville Campbell Skinner; E. B. Smith; H. E. Smith; J. P. Snow; Albert Sommer; Henry S. Spackman Engineering Company, represented by Henry S. Spackman; Herbert Spencer; L. G. Sprague; Samuel G. Stafford; Standard Steel Works, represented by A. A. Stevenson; Standard Underground Cable Company, represented by C. C. Baldwin; A. A. Stevenson; Bradley Stoughton; George F. Swain; Howard Taggart; Arthur N. Talbot; Wirt Tassin; C. Marshall Taylor; W. Purves Taylor; George Thomas, 3d; Gustave W. Thompson; Harry D. Tiemann; Edwin B. Tilt; W. J. Tretch; F. E. Turneure; J. S. Unger; Union Drawn Steel Company, represented by F. N. Beegle; United Gas Improvement Company, represented by W. H. Gartley; United States Gutta Percha Paint Company, represented by Herbert W. Rice; F. F. Vandevort; C. P. Van Gundy; J. L. Van Ornum; S. S. Voorhees; F. R. Wadleigh; Samuel Tobias Wagner; Joseph F. Walker; Percy H. Walker; William H. Walker; George C. Warner; Westinghouse, Church, Kerr and Company, represented by C. M. Chapman; Westinghouse Electric and Manufacturing Company, represented by C. E. Skinner; Frederick A. Weymouth; G. D. White; Max H. Wickhorst; Rudolph J. Wig; The A. Wilhelm Company, represented by E. C. Street, Jr.; H. V. Wille, represented by R. K. Johnson; Percy H. Wilson; Winchester Repeating Arms Company, represented by R. L. Penney; R. D. Wood and Company, represented by Walter Wood; Walter Wood; Julian E. Woodwell; Ira H. Woolson; W. H. Wright; J. Bertram Young.

Total number, 235 (including representations); total number in personal attendance, 219.

FIRST SESSION.—TUESDAY, JUNE 29, 3 P. M.

Business Meeting.

President Charles B. Dudley in the chair.

The minutes of the Tenth Annual Meeting were approved as printed.

The annual report of the Executive Committee was adopted as printed.

The Chair appointed Mr. Robert Job and Mr. Max H. Wickhorst as tellers to canvass the ballot for members of the Executive Committee.

A paper on "The Desirability of Standardizing the Testing of Insulating and Other Materials" was read by Mr. C. E. Skinner.

The annual report of Committee W, on Standard Specifications for Hard-Drawn Copper Wire, was presented by the Chairman, Mr. J. A. Capp. Specifications for Hard-Drawn Copper Wire were submitted by the Committee, and on motion of Mr. Capp they were referred to letter ballot of the Society.

A paper entitled "The Effect of Various Constituents of Coal on the Efficiency and Capacity of Boiler Furnaces," by Mr. D. T. Randall and Mr. Perry Barker, was read by Mr. Randall and discussed.

The annual report of Committee P, on Fireproofing Materials, was presented by the Chairman, Mr. I. H. Woolson, and on motion of Mr. Woolson, the adoption of the proposed Standard Test for Fireproof Partition Construction, accepted by the Society at the preceding annual meeting, was referred to letter ballot of the Society.

The tellers reported that 145 ballots had been cast, and in accordance with their report the Chair declared the election of Mr. W. A. Bostwick and Mr. W. R. Webster as members of the Executive Committee.

The Secretary presented a communication from Mr. W. F. Hillebrand, of the U. S. Bureau of Standards, suggesting that the Society consider the desirability of appointing a committee on the preparation of standard samples, to cooperate with the Bureau of Standards by furnishing samples which the Bureau would

analyze and distribute under suitable regulations. On motion, this recommendation was referred with power to the Executive Committee.

The meeting then adjourned till 8 P. M.

SECOND SESSION.—TUESDAY, JUNE 29, 8 P. M.

President Charles B. Dudley in the chair.

The Chairman invited Mr. Mansfield Merriman, Past President of the Society, to the chair and read the Annual Presidential Address on "Engineering Responsibility."

The following papers were then presented and discussed:

"Notes on Tests of Ingots and Derivative Shapes in Progress at Watertown Arsenal." J. E. Howard.

"The Closing Up of Blowholes in Steel Ingots." H. M. Howe.

"Further Investigations of Broken Steel Rails." Henry Fay and R. W. G. Wint.

"An Investigation of a Defective Open-Hearth Steel Rail." Robert Job.

The meeting then adjourned till the following morning.

THIRD SESSION.—WEDNESDAY, JUNE 30, 10 A. M.

On Steel.

President Charles B. Dudley in the chair.

At the invitation of the Chairman, Mr. C. E. Munroe spoke briefly on the subject of explosives. On motion of Mr. Munroe, the recommendation that a committee on explosives be organized, was referred to the Executive Committee.

The annual report of Committee A, on Standard Specifications for Iron and Steel, Mr. W. R. Webster, Chairman, was presented by Mr. Edgar Marburg, Secretary of the Committee.

The proposed revised and new specifications embodied in this report were accepted after discussion without amendment, and on motion of Mr. J. P. Snow were referred to letter ballot of the Society.

On motion of the Secretary, the recommendation of Committee A, that the Committee hereafter be designated as "Committee on Standard Specifications for Steel," and that a new committee on the special subject of Standard Specifications for Wrought Iron be appointed, was referred to the Executive Committee with power.

On motion of Mr. J. P. Snow, the recommendation that Committee A consider the use of the small letter for the initial letter of "Bessemer" in all cases where it is employed, was passed.

The annual report of Committee F, on Heat Treatment of Iron and Steel, was presented by the Chairman, Mr. H. M. Howe.

The following papers were then read by title:

"Some Notes on the Heat Treatment of Steel." William Campbell.

"Detailed Fractures of Cold-Rolled Rails at Low Temperatures." P. H. Dudley.

"Elongation and Ductility Tests of Rail Sections Under the Manufacturers' Standard Drop-Testing Machine." P. H. Dudley.

"Dark Carbon Streaks in Segregated Metal of 'Split Heads' of Rails." P. H. Dudley.

The annual report of Committee O, on Standard Specifications for Coal, was presented by the Chairman, Mr. J. A. Holmes.

A report on "Fuel Investigations, U. S. Geological Survey: Progress During the Year Ending June 30, 1909," was read by Mr. J. A. Holmes.

A discussion on the subject of Coal followed.

The meeting then adjourned till 8 P. M.

FOURTH SESSION.—WEDNESDAY, JUNE 30, 8 P. M.

President Charles B. Dudley in the chair.

The following papers were read and discussed:

"Measurement of Impact Stresses." B. W. Dunn.

"The Testing of Galvanized and Other Zinc-Coated Iron." W. H. Walker.

"Tests of Standard I Beams and Bethlehem Special I Beams and Girder Beams." Edgar Marburg.

"The Permanent Mold and Its Effect on Cast Iron." E. A. Custer.

The meeting then adjourned till the following morning.

FIFTH SESSION.—THURSDAY, JULY 1, 10 A. M.

On Steel and Iron.

President Charles B. Dudley in the chair.

The annual report of Committee U, on the Corrosion of Iron and Steel, Mr. A. S. Cushman, Chairman, was read by Mr. W. H. Walker, Secretary of the Committee. This was followed by a general discussion on the subject of Corrosion of Iron and Steel.

A paper comprising "Notes on Tests of Steel Columns in Progress at Watertown Arsenal" was presented by Mr. J. E. Howard and discussed.

A paper on "The Physical Quality of Steel which has been Subjected to Compression during Solidification" was read by Mr. Bradley Stoughton. The formal discussion of this paper was opened by Mr. H. M. Howe and Mr. J. E. Howard.

The annual report of Committee V, on Standard Specifications for Cold-Drawn Steel, was presented by Mr. C. E. Skinner, Chairman.

A paper entitled "An Interesting Driving Axle Failure" was read by Mr. M. H. Wickhorst.

The annual report of Committee D, on Standard Specifications for Paving and Building Brick, was presented by the Chairman, Mr. L. W. Page.

The meeting then adjourned till 3 P. M.

SIXTH SESSION.—THURSDAY, JULY 1, 3 P. M.

On Cement and Concrete.

Vice-President Robert W. Lesley in the chair.

The annual report of Committee C, on Standard Specifications for Cement, was read by the Chairman, Mr. George F.

Swain. On motion of Mr. R. L. Humphrey, the amendments of the Standard Specifications for Cement embodied in the report were accepted and passed to letter ballot of the Society.

The annual report of Committee I, on Reinforced Concrete, was presented by Mr. F. E. Turneure, Chairman. On motion of Mr. R. L. Humphrey the report was accepted for publication in the Proceedings.

A paper on "Tests of Plain and Reinforced Concrete Columns," by Mr. M. O. Withey, was, in the absence of the author, read by Mr. F. E. Turneure and discussed.

Then followed the reading and discussion of the following papers:

"A Suggestion as to a Commercial Use to be made of Cement Testing." R. K. Meade.

"Further Tests of Reinforced Concrete Beams under Oft-Repeated Loading." H. C. Berry.

"Tests of Bond of Steel Rods Imbedded in Concrete by Three Methods." H. C. Berry.

"Concrete Reinforced by Nails." L. S. Moisseiff.

The annual report of Committee S, on Waterproofing Materials, was presented by the Chairman, Mr. W. A. Aiken.

The meeting then adjourned till the following morning.

SEVENTH SESSION.—FRIDAY, JULY 2, 10 A. M.

President Charles B. Dudley in the chair.

A paper entitled "Paints for Concrete: Their Need and Requirements," was read by Mr. G. D. White and discussed.

The annual report of Committee E, on Preservative Coatings for Iron and Steel, was presented by the Chairman, Mr. S. S. Voorhees.

The report of the sub-committee of Committee E, on Linseed Oil, was read by Mr. G. W. Thompson, Chairman.

The report of the joint sub-committees from Committees E and U, on the Investigation of the Inhibitive Power of Certain Pigments on the Corrosion of Iron and Steel, was presented by Mr. S. S. Voorhees, Chairman *pro tem*.

This was followed by a general discussion on Preservative Coatings.

On the invitation of the Chairman, Mr. Mansfield Merriman, Past President of the Society, occupied the chair for the remainder of the session.

The following papers were then read:

"Principal Features of a 1,200,000-lb. Testing Machine, with Special Reference to a New System of Transmitting the Pressure Developed in the Hydraulic Cylinder to the Scale Beam." T. Y. Olsen.

"A Machine of New Design for Hardness Tests." T. Y. Olsen.

"Notes on the Bearing Value of Rods Imbedded in Concrete." R. A. Cummings.

"Some Tests of Concrete Piers under Varying Heights and Bearings." Edgar Marburg.

A paper on "Disintegration of Fresh Cement Floor Surfaces by the Action of Smoke Gases at Low Temperatures," by Mr. A. H. White, was read by title.

The meeting then adjourned till 3 P. M.

EIGHTH SESSION.—FRIDAY, JULY 2, 3 P. M.

On Bitumens and Oils.

President Charles B. Dudley in the chair.

The annual report of Committee H, on Standard Tests for Road Materials, Mr. L. W. Page, Chairman, was read by the Secretary of the Committee, Mr. Prévost Hubbard. Proposed Standard Tests for Bituminous Compounds for Roads and Pavements were submitted by the Committee; but in view of the fact that the Secretary of the Committee, in the absence of the Chairman, was not positive of the wishes of the Committee, the adoption of the tests as standard was, on motion, referred to letter ballot of the Society, provided the Committee unanimously recommended such procedure.

The following papers were presented and discussed:

"The Effect of Free Carbon in Tars from the Standpoint of Road Treatment." Prévost Hubbard.

"Improved Instruments for the Physical Testing of Bituminous Materials." Herbert Abraham.

"Notes on Testing Turbine Oil." Robert Job.

The following papers were then read by title:

"Methods for the Examination of Bituminous Materials for Road Construction." Clifford Richardson and C. N. Forrest.

"Bituminous Materials for Use in and on Road Surfaces and Means of Determining Their Character." Clifford Richardson.

"Viscometer for Heavy Road Oils." A. W. Dow.

"A Machine for Testing the Ductility of Bituminous Paving Cements." F. P. Smith.

"A Further Development of the Penetrometer as Used in the Determination of the Consistency of Semi-Solid Bitumens." C. N. Forrest.

"Conditions Affecting the Determination of Carbenes in Bitumens of Carbon Tetrachloride." C. N. Forrest and D. B. W. Alexander.

A discussion of the above papers, and of Bituminous Materials in general, followed.

The meeting then adjourned till the following morning.

NINTH SESSION.—SATURDAY, JULY 3, 10 A. M.

Past President Mansfield Merriman in the chair.

The annual report of Committee B, on Standard Specifications for Cast Iron and Finished Castings, was read by the Chairman, Mr. Walter Wood. Inasmuch as the proposed revised Standard Specifications for Foundry Pig Iron embodied therein had not previously been submitted to letter ballot of Committee B, the Secretary was instructed by vote of the meeting to first refer these proposed revised specifications to the vote of the Committee, and in case the vote should be unanimous, to refer the specifications to letter ballot of the Society.

The annual report of Committee K, on Standard Methods of Testing, was presented by Mr. Gaetano Lanza, Chairman.

A paper entitled "Some Results of Dead-Load Bending Tests

of Timber by the Use of a Recording Deflectometer" was read by Mr. Harry D. Tiemann.

A paper on "The Effect of Tension on the Shearing Strength of Rivet Steel," by Mr. E. L. Hancock, was read by title.

A report on "The Structural Material Testing Laboratories, U. S. Geological Survey: Progress During the Year Ending June 30, 1909," was presented by Mr. R. L. Humphrey and discussed.

The annual report of Committee L, on Standard Specifications for Clay and Cement Sewer Pipes, was read by the Chairman, Mr. Rudolph Hering.

The annual report of Committee Q, on Standard Specifications for the Grading of Structural Timber, Mr. Herman von Schrenk, Chairman, was read by title.

The following proposed amendments to the By-Laws, recommended by the Executive Committee, were referred to letter ballot of the Society:

To strike out Sec. 3, Art. V; viz.,

Any member of the Society whose dues shall remain unpaid for the period of one year shall forfeit the privileges of membership. If he neglects to pay his dues within thirty days thereafter, and after notification from the Secretary, his name may be stricken from the roll of membership by the Executive Committee,

and to substitute the following new sections:

SEC. 3. Any member of the Society whose dues shall remain unpaid for a period of three months from the beginning of the fiscal year shall receive a "Second Notice" from the Treasurer; if his dues shall remain unpaid for a period of five months from the beginning of the fiscal year, he shall forfeit the right to vote and to receive the publications of the Society. A month before the close of the fiscal year, he shall receive a final notice from the Treasurer that, if he neglects to pay his dues before the end of the fiscal year, his name may be stricken from the roll of membership by the Executive Committee.

SEC. 4. Any person elected after six months of any fiscal year shall have expired, shall pay only one-half of the amount of dues for that fiscal year; but he shall not be entitled to a copy of the Proceedings of the previous annual meeting.

SEC. 5. The resignation of a member whose dues for the current fiscal year are unpaid, shall be acceptable only if it be received within one month from the beginning of the fiscal year, unless an exception be authorized by special action of the Executive Committee.

SEC. 6. Charges for cloth and half-leather binding for the Proceedings shall be payable in advance.

The following resolution was passed:

Resolved, That it is the unanimous sense of the members of the American Society for Testing Materials, assembled at the Ninth Session of the Twelfth Annual Meeting, that they are voicing the general sentiment of the Society in expressing the hope that the invitation to be conveyed to the International Association for Testing Materials through President Dudley, that the Sixth Congress of the Association be held in this country, will be favorably entertained.

The following resolutions were then referred to letter ballot of the Society:

Resolved, That it is the sense of the American Society for Testing Materials, that it is desirable that the testing facilities of the country be increased by the construction of a testing machine, or machines, of sufficient capacity for testing large structural members; and, be it further

Resolved, That this project is believed to be eminently deserving of the support of the Federal Government, to the end that such a machine may become available also under suitable restrictions for research tests of materials and structural members, with the cooperation of engineers not necessarily connected with the Government Service.

The Chairman then declared the meeting adjourned *sine die*.

AMERICAN SOCIETY FOR TESTING MATERIALS.

AFFILIATED WITH THE
INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

PROCEEDINGS.

This Society is not responsible, as a body, for the statements and opinions advanced in its publications.

ENGINEERING RESPONSIBILITY.

ANNUAL ADDRESS BY THE PRESIDENT.

Few fields of study are more fruitful of results and lead to more genuine progress than a study of the causes of failures. Such studies may be unpleasant and disagreeable, they may at times be even disheartening, but the man who would make substantial advances must heed the lessons which his failures teach. It is true that valuable information can be obtained likewise from a study of materials which have given successful service. And, oftentimes, when attacking a new problem, a comparison of the properties and characteristics of those parts of a structure which have behaved well in service with the characteristics and properties of those which have failed in the same service, is a most satisfactory method of approach. And yet, it is doubtful whether the study of failures does not give the more positive information. Faraday, who spent his life in experiment, used to say that he learned more from his failures than he did from his successes. And it is not difficult to see why this should be so. When an experiment or a construction has proved successful we are naturally most interested in the result, and do not usually spend time and thought and study over the details which have led to our success. On the other hand, if our experiment or construction is a failure, the cause of the failure is immediately sought for, every detail is questioned,

and it is this study of the details which broadens our knowledge. Quite in line with Faraday's statement is the rather more homely phrase, with which you all are doubtless familiar, and which we remember to have seen somewhere in engineering literature, that "the scrap heap is the place to learn."

Closely connected with the query as to the cause of failure is the oftentimes more important question, who is responsible for the failure? If the matter in hand is an experiment which we are making for our own information, the question of responsibility is small and is practically swallowed up in the cognate question of the cause of the failure. But if, on the other hand, the failure involves the loss of human life or the destruction of valuable property, the question of responsibility may be very grave. And if we may trust our observation, the location of the responsibility for failure is not always an easy matter. I remember to have heard a former editor of Harper's Magazine say in a public lecture: "The general habit of humanity is to throw the teaching of the sermon over into the adjoining pew and keep practically none of it for ourselves." Much the same way is it with responsibility for failures. With each and all of us it is usually the other fellow and not ourselves that should be held accountable. In view of the situation it has occurred to us that it might not be amiss on this occasion to spend a little time over the cause of, and responsibility for, failures in engineering constructions.

In our studies of failed and broken parts in connection with our work at Altoona for now some years, we have been gradually led to ascribe failures to one or more of the four following causes, viz., to bad material, bad workmanship, bad or faulty design, or to unfair treatment.

Let us spend a few moments with each of these possible causes of failure. First, bad material. This does not cover those cases where the wrong kind of material was used or material not adapted to the work. If cast iron is used when steel should have been employed, if the steel is brittle when the service requires tough, tenacious metal, this is no fault of the material. Failures due to the employment of material unfitted to the service come under another category. Nor can the material be blamed if the size of the part which fails is too small. This cause of failure also comes under another category. But material is bad, and may

justly be charged with being the cause of failure, when it is different from what those who put it in service had a reasonable right to expect it to be. A rail with a bad pipe in the head, an axle made from a badly segregated bloom, a piece of concrete in which the materials are improperly mixed or contain not enough or inferior cement, are all examples of bad material, and if failure comes the failure may justly be charged to the material.

The query may naturally arise here, ought not the factor of safety employed to be sufficient to care for the uncertainties of material, so that the total output of a works could be made use of in service? We once knew an officer of a steel works who wanted to have one grade of steel used for all purposes, and who, when told that car axles made of that grade of steel would not be strong enough to hold up the load, replied: "Use more of it; that is, make the axles bigger." Undoubtedly there is a necessary relation between the factor of safety and some of the uncertainties of manufacture, but it can hardly be allowed that the producer should thus throw upon the consumer all the uncertainties of material. We cannot help thinking that our definition of bad material is sound, viz., material is bad when it is different from what those who put it in service had a reasonable right to expect it to be. If the material is bought on specifications, it is reasonable that it should be what the specifications call for. And even if it is bought on indefinite, verbal or written order, such material should be supplied as the buyer had a reasonable right to expect would be furnished.

But why is there ever any difficulty between the producer and consumer about material? The price is agreed upon when the order is taken and the quality of the material is either specified or understood. Why, then, does not the producer always furnish good material?

Our experience on this point has brought us face to face with several explanations of the difficulty we are considering. First and perhaps most important is the price. It is constantly urged that the consumer will not pay the price requisite to secure the materials desired. No information is usually given as to how far the wished-for price, requisite to secure such good materials as the producer would like to furnish, covers a desire for large profits, and consequently consumers have always been a little slow in

attaching much weight to this excuse. Prices are largely determined by competition, and in the absence of something more than a verbal statement from the producer that better materials would be furnished at a higher price, he would be a bold purchasing agent that would pay the higher rate. On the other hand it is undoubted that competition is the antagonist of quality, and where materials are bought without reasonable specifications rigidly enforced there is unquestionably much weight in the contention of the producer.

Another reason or excuse for poor materials is that processes and methods of manufacture do not always and every time yield the desired first quality product. Strive as the manufacturer may, the works always turn out some material that is inferior. Taking our illustration from the steel industry, it is well known that every heat is not equally as good as every other, and that a part of each ingot is inferior to the remainder of it. Of course, all of this inferior part that cannot be sold must necessarily remain as scrap, to be worked over again, with the result that the manufacturing cost of the marketable product is necessarily increased. Hence the tendency to crowd the limits and force upon the purchaser all the merchantable material possible, even though some of it may be inferior. It is fair to say that there is a good deal of human nature in this phase of our subject, and if only those of us who are without sin are entitled to cast stones we greatly fear very few stones will be thrown.

Another and most pernicious excuse for furnishing bad materials is the attempt so common everywhere on the part of producers to usurp the legitimate functions of both the consumer and his expert. This manifests itself in the statement, so commonly made by those furnishing material, that it is good enough for the purpose, thus arrogating to themselves the right to decide not only how the material shall be made, but also what kind of material the consumer and his engineer shall use. Pernicious though this custom may be, a good deal may be said in palliation of it. The practice is the outgrowth of an historical situation. In the earlier days, when the consumption of materials was only a fraction of what it is at present, the producer of any material was supposed to know not only how to manufacture it, but also its characteristics and how it would behave in service, and consequently consumers

who in those days had scarcely begun to study for themselves the behavior of materials in service, naturally turned to the manufacturers for counsel as to what materials to use. This practice is still in vogue, and it is to be confessed that, where it is employed, no legitimate criticism of the producer can be made if he urges that the material is good enough for the purpose. On the other hand, as time progressed, and large consumers began to study for themselves the behavior of materials in service, as they began to employ their own experts, as testing machines and laboratories began to increase, as, indeed, a society for testing materials came into existence and knowledge of the properties and characteristics of materials began to widen, it is evident that the situation has changed and that where materials are bought on definite specifications, the voice of the producer as to quality is no longer potent, and that the old excuse for inferior materials, that they are good enough for the purpose, is no longer entitled to consideration or weight. We are entirely ready to allow that the study of materials, during both the process of manufacture and their behavior while they are in service, is a legitimate field of activity for both producer and consumer, and, as is well known, we have persistently urged with all the force that we were capable of, that while specifications are being made there should be the heartiest cooperation on the part of both; but the specification having been decided on and the contract placed in accordance therewith, there really seems to be very little room left for excuse for furnishing materials that do not meet the requirements, because they are, in the judgment of the producer, good enough for the purpose.

We intentionally refrain from discussing that excuse for poor materials which has its foundation in an overweening desire to make money, since it is so clear that the producer who does not give a reasonable equivalent for the money that he receives must necessarily have a short business life. We are quite ready to acknowledge that no hard and fast line can be drawn between quality and continued business success, and yet we fancy few will deny that the man who sells inferior, worthless or adulterated materials which do not give satisfaction at the price of good ones, will have serious difficulty in securing a second or third order for the same kind of goods. In our own experience, and, let it be stated modestly, partly as the result of our own tests, a number of

firms who formerly did quite large business with railroads, have either gone out of existence or have been forced to seek business in other fields than those which they formerly cultivated with such unfair profit to themselves.

Coming now to the second cause for failure in structures, bad workmanship. That bad workmanship is a far too frequent cause of failures, is common experience. The tendency to slight the job is almost universal. A rivet or a bolt is left out, with consequent increased strain on those which are actually put in, a forging does not fill out the pattern, or the metal is burned, or a weld is defective. We knew a case once where the construction on a passenger coach involved the safety of human life, and where the drawings required that there should be two nuts on a bolt and the end of the bolt riveted over. After the cars had been in service a few weeks and some minor repairs were being made, it was discovered that the bolts originally used in a number of the cars were too short, that the second nut only grasped one or two threads, and that the remaining space in the nut had been filled with putty, so manipulated and stained as to give the appearance of the riveted end which the drawings called for. We knew of another instance where two ends of a gas pipe in a small house were joined with putty, instead of with the well-known sleeve or thimble. Fortunately the odor of the gas from a slight leak in the defective joint led to its discovery and repair before anything serious happened. There is little doubt that the experience of each of you will furnish quantities of cases of bad workmanship, and we have known engineers who did not hesitate to declare that bad workmanship was the principal cause of failures in service.

Those of you who have frequently been brought into contact with the results of bad workmanship, have no doubt, like myself, often wondered why work was so badly done. Not infrequently, in contemplating a failure in which bad workmanship played an important part, we have said to ourselves, "there was absolutely no excuse." And yet, since workmanship is so important an element in our theme, it may not be amiss to go a little deeper into the matter. Every one will recognize lack of skill, general inefficiency, and simple plain laziness as important elements in bad workmanship. But since these are individual characteristics, it probably would not yield any valuable results to discuss them. It is true

that the apprentice system or lack of apprentice system which is characteristic of many trades might, perhaps, justly be blamed for lack of skill, but it would lead us too far to consider this point.

No doubt many will claim that inferior or insufficient compensation is the most fruitful cause of poor quality of work at the hands of those who, in our industrial system, play the part of hewers of wood and drawers of water. But if we are right, the experience of the last few years has not seemed to confirm this view. If this was the real explanation it would seem to necessarily follow that a voluntary increase in wages would bring an increase in efficiency. On the other hand, if we may trust the indications that we have been able to gather, the increase in efficiency following voluntary increases in wages has been most disappointing. We must apparently look further for the real reason for poor workmanship.

In our judgment, the method of compensation for work performed has a direct and most important influence on the quality of the service rendered. We refer especially to the piecework system in those places where it is applicable, and to the payment of all interested in proportion to the amount of successful output, which is so common in the steel industry. Both these methods of compensation stimulate output at the expense of quality, and it is not at all strange, perhaps, that after constructions have found their way into service, we should not infrequently find evidences of the haste, the slurring over, and the inferior workmanship which these methods have necessarily done so much to stimulate. We are not at all prepared to suggest any substitute for them, and we are, and have been for many years, an advocate of them from the standpoint of successful management; but it is folly for us to close our eyes to the fact that the piecework and successful output methods of compensation of workmen are antagonistic to quality of work, and that, despite all our efforts to the contrary, they may justly be held responsible for some of our engineering failures.

One more phase of the workman problem. Close observers of the modern workman have noticed for some years a growing tendency on his part to manifest less and less interest in his work. *Esprit du corps*, pride in his work, and a genuine feeling of loyalty and devotion to the establishment of which he forms a part, are

gradually becoming less and less. The allegiance of the workman, under the influence of the ferment and agitation which now pervades our whole industrial system, is gradually passing over, in a measure at least, to the labor organization. Instead of cooperation there is oftentimes antagonism. Instead of zeal and earnestness on the part of the workman to do his best, there is study how to make the organization stronger and secure greater benefits for himself. The effect of this transfer of allegiance on the quality of the work performed needs no elucidation.

It is not at all our purpose to discuss the labor problem, and this statement of the situation is cited only because it throws a valuable side light on the question we are considering. We may, however, be permitted a single statement, viz: "We are firmly convinced that if labor organizations would devote less time and energy to contention with employers and more effort toward making the organization stand for skill and plain, simple honesty in workmanship, and for fair dealing with, and reasonable devotion to, the interests of employers, all questions connected with the recognition of the union would fade into insignificance, and collective bargaining would be welcomed, nay, even sought for, by those who are managing the great industries of our modern civilization."

Third, it is evident that the engineer who makes or finally decides upon the design of any structure carries a heavy load of responsibility. He is first in the field and practically tells all who follow what is to be done. He must decide not only the kind of material that is to be used, but also the amount or sizes, and how it shall be disposed. His realm embraces every kind of structure, from the foundations of a bridge or building to the most minute detail of a locomotive or car. In railroad track he says or should say what weight of rail shall be used, the number of ties per rail, and the kind and depth of ballast. His knowledge of the properties of materials used in construction must necessarily be broad and comprehensive, and the field is so enormous that there are naturally numerous specialists, each being able to cover, and be an authority in, only his own little paddock.

The engineer who makes the design labors under two very serious difficulties. First, it is not possible, many times, to compute the strains to which the whole or parts of the structure will be subjected. Perhaps we can best make this point clear by con-

sidering the locomotive driving axle. The strains produced, when we regard the locomotive as a vehicle, are simple and easily determined. So likewise the bending moment produced by the action of the steam on the piston, as well as the torsion strain produced by the crank. But who can tell the bending moment produced by the lurch when the wheel strikes a curve at high speed? Who can even give a guess at the strain produced when the brake is applied, making an emergency stop at sixty miles an hour? Moreover, the tendency of the times is toward larger and larger structures. And as the parts increase in size, would any of us be willing to say that the strains in each part would increase directly proportional to the increase in size of the whole structure, or that a proportional increase in size of any given part would as successfully meet the increased strains as did the corresponding smaller parts of the original structure? The engineer who makes the design, perhaps more often than any of us, is at the end of his knowledge and, if failure comes due to defective or faulty design, deserves, in our opinion, more sympathy than any one else involved.

But the designer labors under another serious difficulty. He is often overruled and prevented from doing what his judgment prompts him to do, in the interests of safety, by those who control expenses. The construction he would like to use costs more, and the management for economic reasons demands something less expensive. Of course, under these conditions, much responsibility is taken off the designer. And while we are ready to allow that some check is desirable, since those who make the design are, after all, human and naturally will take care of themselves, we cannot but feel that this check should be sparingly applied in all places where safety to human life is involved.

Fourth, unfair treatment. As already indicated, there is a natural disposition on the part of each of us to relieve ourselves from blame and put the fault on some one else, and if our observation is worth anything there is no field of parceling out deserts among those involved in failures and the responsibility therefor more fertile than this one of unfair treatment. This field is the especial paddock of the maker or producer of material. If a rail breaks or fails in service there was, says the rail maker, something wrong with the track or with the locomotives or cars that run over it. If a car wheel breaks or fails to give the guaranteed mileage,

the track was too rough, the use of the brakes too severe, or the lading too heavy, and so on. Far be it from us to say that unfair usage is not many times a legitimate explanation of failures. If a freight locomotive, designed to haul a heavy load at twenty miles an hour, is used at times on a passenger train at forty miles an hour, and in so doing shakes herself to pieces, the fault is certainly not in the materials nor in the workmanship, nor in the design, but in the unfair use. If, due to the growth in size of locomotives and cars, an old iron bridge, designed for not over two-thirds the live load which is actually put upon it, gives way and produces a disaster, the responsibility rests with the operating officer rather than with the bridge engineer. These examples might be multiplied to almost any extent, but perhaps enough has been said to make the point clear.

There is, however, another phase of this part of our subject. Unfair treatment is very much broader than the obvious misuse of a bridge or of a moving vehicle. The materials entering into a structure may be unfairly treated. If the calculated strains are too high, or, what amounts to the same thing, too low a factor of safety is employed, materials are unfairly used. Still further, where a structure is composite it may, and undoubtedly does, often happen that the elements making up the composite are unfairly treated, as when, for economic reasons, not enough money is spent to properly install the structure. For example, a steel rail called upon to do its work supported by too few ties, insufficient ballast, and a badly drained sub-grade, is unfairly treated. Moreover, the state of repair in which structures are maintained is clearly an element in their fair treatment. If not enough money is spent in repairs and parts become weakened by decay, corrosion, or wear to such an extent that failure results, it is entirely obvious that the failure must be attributed to unfair treatment.

We have gone thus quite at length into detail in what has preceded in order that we might have definitely before us the elements entering into this problem and be able to see more clearly where truth and justice lie between the conflicting interests. If now our analysis of the causes of failure is accepted as correct, it is evident that freedom from failure in construction depends on the conscientious and intelligent action of four different contributors to the final result. The materials employed must be conscientiously

and intelligently made, and must be what they are supposed to be. The workmen who use these materials must do their work conscientiously and under intelligent guidance. The engineer who designs the structure must have abundant knowledge of the properties of the materials he is using and must take as little as possible for granted in deciding on shapes, sizes and kind of materials to be employed. And, finally, the one who installs and operates the structure, when it is completed, must keep it in proper repair and look well to it that no duty is required of it which subjects it to unfair strains.

It is likewise evident that, since the four parties involved in successful construction have different individualities and may have diverse and even antagonistic interests, there is abundant reason why there should be an attempt to shift responsibility for failure. And, indeed, we might perhaps safely go a step further and say that there is abundant reason why each of the four parties should try to limit the part which his own work plays in the final result, and say plainly, if the other three had done as they should there would have been no failure. The man who furnishes the material is tempted to say: "If the designer had allowed a proper factor of safety everywhere, if the workmen had done their duty, and if the structure had received only proper fair treatment, almost any material would have been good enough." The engineer who makes the design is tempted to say: "If the material had been what I had a right to expect it to be, if the workmen had done good work and there had been no abuse of the structure in service, there would have been no failure." And so on, for the others. It is plain that the problem of obtaining successful constructions is a complicated one, and that the chances for divided responsibility which are involved are no small element in this problem.

Within the last few months two episodes have occurred which so clearly illustrate two phases of our theme that we cannot forbear to quote them. The two phases are unfair treatment and the inference that the blame for failure rests on some one else. It will be remembered that within the past two or three years there has been much outcry in regard to broken steel rails, and the steel rail manufacturers have, in the technical press, been quite severely called to account for their shortcomings. Indeed, from this platform, in the last annual address, some statements were made indi-

cating that it was believed that the maximum fiber stress in the 100-lb. rail under present conditions of wheel loads and speed was not over 12,500 lbs. per sq. in. Some two months ago we received a letter from one of the ablest metallurgical engineers connected with steel rail manufacture in this country, in which this statement was very seriously called in question. The writer of the letter figured that under many conditions the fiber stress might be double the figure given, and that under extreme, but still possible, conditions the fiber stress might reach nearly four times this figure. The obvious conclusion was, although this was not stated in the letter, that it was these extreme fiber stresses, this unfair treatment, which caused the rails to break. We have tried in vain thus far to get some one much more competent than ourselves to prepare a paper on this subject for this meeting, and one object we have in mind in citing it now is to stimulate study and attention to it. Will not some one take hold of this problem and give it exhaustive treatment, allowing the maximum effect to wheel loads, counter-balance, effect of the steam, want of rotundity, flat spots, nosing, and speed? A theoretical treatment, even though we are not all satisfied that the rail acts like a continuous girder supported at the centers of the ties, cannot fail to be valuable.

The other episode is the experience of the Atchison, Topeka and Santa Fé Railroad with broken rails on different sub-grades. This road had some 227 miles of roadbed which were sandy, porous and well drained, and 91 miles which were largely clay of a kind that holds water. The traffic was the same over both portions and the rail all 85-lb. rail. The rail breakages in one year were two and a half times greater per mile of track on the clay sub-grade than they were on the sandy sub-grade. Mr. Wells, the general manager of the road, was kind enough to say, in communicating this information, that these facts seemed to confirm the statement made in the last year's annual address that "there are indications that rail failures are a question of geography." More to the point for our present discussion is the obvious conclusion that the use of rails on clay sub-grade full of water without sufficient porous ballast is unfair treatment, and that breakages, under such conditions, cannot justly be said to be the fault of the rail.

But perhaps we have said enough in analysis of the causes of failure. Let us now devote a few moments to precautions that

may be taken with material and workmanship in the interests of safety; and to a consideration of what should be our mental attitude toward design and unfair treatment. And first as to workmanship. Under present conditions the necessity for close supervision is evident. Managing men everywhere recognize this necessity and are employing all means at hand to secure it. We knew an officer of a large corporation some years ago who said to his board of directors: "If you will allow me to spend \$50,000 a month more in salaries, so that I may give your work better supervision, I will give it back to you four-fold." Moreover, with the growth of modern industry, and especially with the development of machinery as an element in this growth, the individuality of the workingmen has necessarily diminished, and the present industrial ferment of strikes and lockouts, with their accompanying riots and violence, is, as we interpret it, the revolt against this debasement of individuality. That the revolt should at times go too far, that unreasonable demands should be made, that demagogues and agitators for their own advancement should get into positions of prominence, is perhaps to be expected. As time progresses these will pass. It takes time to bring a change of views in both employed and employers. Already there are signs of something better and our belief is that in the not far distant future, as the result of wiser management on the part of labor organizations and reasonable concessions on the part of employers, there will be a return by the workingmen to the old-fashioned virtues of interest and pride in their work, and unswerving loyalty to the organizations which they serve. The effect of this change on the quality of workmanship needs no comment.

Second, with regard to material. It is difficult for us to see how any one who is responsible for safety in structure dare at the present time put material into these structures which has not been bought on carefully prepared specifications, and which, before acceptance, has not been rigidly inspected and tested. In time past, before consumers understood the demands which the service makes on materials, the reputation of the maker was perhaps the best safeguard known for good materials and was accepted as reasonable defense in the investigations following disaster. But in these days, when the service has been so frequently questioned, when so much accumulated information is available, when experts

and facilities for testing are so largely multiplied, we cannot help feeling that the management that puts materials into service, especially where safety is involved, without careful and conscientious inspection and testing, is taking a risk that it is no longer entitled to assume. It is gratifying to be able to see that, as the years go by, there is constant and steady growth in this field. And while the ground is still far from being covered and the number of standard specifications still far too small, each year brings some progress, some steps forward. This society has a most important mission to fulfill, and the publications of no organization that we know of anywhere are doing more to elevate the standard of quality of materials of construction than the annual volume giving the results of the deliberations of this body.

Third, bad workmanship and bad materials can apparently be so controlled as to secure safety by sufficient supervision and by having proper specifications, with rigid inspection and test. But how about the unfair treatment of materials, or the structure made from them? Here no supervision beyond some meager legislative enactments and the condemnation of public opinion in case of disaster, is possible. It is, of course, true that those in charge of the construction and operation of utilities in which the public safety is involved are constantly face to face with the possibilities of heavy losses in the way of damages for accidents, and no doubt this is a most powerful check against unfair treatment. But it has seemed to us for a long time that the producers of material have far too much neglected their opportunities. Surely it is as legitimate that the producer should study the treatment his material gets in service, as that the consumer should study the methods by which that material is made. It may take the consumer a few years to become familiar with the idea of being told that he has not treated material fairly, since he is undoubtedly accustomed now to thinking that he can do what he wishes with what he has bought and paid for; but we are confident there would have been fewer complaints of material in the past if the method we have suggested had been in vogue. It is, of course, not to be understood that we are recommending howls about unfair treatment as excuses for inferior materials. What we have in mind is that careful studies and investigations should be made by the producer, leading up to demonstrations if possible. It is common experience that the

truth is reached with much greater certainty and speed if a problem is attacked by two parties who approach it from different standpoints and are actuated by antagonistic interests. Our whole Anglo-Saxon jurisprudence is founded on this method of procedure.

Fourth, what shall we say of the engineer who makes the design? We have already described his difficulties, pointed out his limitations, and expressed our sympathy with him in his chance failures. It remains to put on record a few thoughts which have forced themselves on us, not once but many times, while preparing this paper, as especially when contemplating the difficulties of the engineer who makes the design. The truth is we are using materials in construction without sufficient knowledge. There is crying need for experiment. Testing machines, adequate to cope with some of the problems which now confront engineers, do not exist. We are increasing sizes and constantly building larger structures. If the test of service gives a failure it simply proves that our guess as to the increase needed was wrong; and if the test of service shows freedom from failure we still do not know that we have used material wisely and economically. The factor of safety everywhere is largely a guess. The late A. L. Holly, one of the brightest mechanical engineers in this country twenty-five years ago, used to speak of "the ridiculous factor of safety, one-half of which is a factor of ignorance." We cannot help feeling that no better use could be made of some small fraction of the millions that have been accumulated by individuals in connection with our great industries during the past half-century, than in the establishment of a Bureau of Engineering Research. Who will avail himself of this magnificent opportunity?

Just a word in conclusion. No one, I am sure, can contemplate the situation which we have been trying to discuss, without being impressed with the diverse and oftentimes antagonistic interests involved. The producer of material is anxious to secure the largest amount of successful output and the greatest possible amount of reward therefor. The consumer wants to limit this by restrictions as to quality and to obtain the material at the lowest possible figure. The workman's interest is to secure the maximum of pay for the minimum of effort, and in this struggle it may perchance happen that the quality of work suffers. The employer's interests are clearly the reverse of the workman's, and so on. The

foundations of these diverse interests are of course very deep, and with the present organization of society it is not easy to see how they are to be obliterated or their antagonism neutralized. But we beg to make one suggestion. Would not an infusion of genuine conscientiousness into our industrial life bring an amelioration? If a little less energy was expended in the mad race for wealth and a little more zeal manifested in maintaining the rugged virtues of honesty, integrity and fair dealing, would not some of the friction and contention of our present commercial life disappear? We must all live together, and surely harmony is better than contention. There are some things in life of more value than money.

REPORT OF COMMITTEE A ON STANDARD SPECIFICATIONS FOR STEEL.

Committee A held two largely attended meetings during the year to consider the revision of the following specifications originally adopted in 1901, and not revised since that time:

- (a) Standard Specifications for Structural Steel for Ships.
- (b) Standard Specifications for Structural Steel for Buildings.
- (c) Standard Specifications for Open-Hearth Boiler Plate and Rivet Steel.
- (d) Standard Specifications for Steel Splice Bars.
- (e) Standard Specifications for Steel Tires.
- (f) Standard Specifications for Wrought Iron.

At these meetings the modifications of these specifications recommended by sub-committees previously appointed to consider the revision of individual specifications were discussed, amended, and passed to letter ballot of the Committee.

The specifications now recommended for adoption by the Society are appended to this report. The proposed specifications for ships, buildings, open-hearth boiler plate and rivet steel, and steel tires, have been largely re-written. The proposed specifications for steel splice bars are changed only to the extent, first, of omitting the previously prescribed limits of carbon and manganese, and retaining only the previous limit for phosphorus; second, of changing the reference to the location of the test piece from "the head of the splice bar" to "the splice bar."

The Committee found itself unable to agree on specifications for wrought iron, and in view of the many uses to which wrought iron is applied, requiring different specifications, the Committee recommends that a special committee on standard specifications for wrought iron be appointed, and that the designation of Committee A be changed to that "On Standard Specifications for Steel."

The Committee also recommends that the present standard specifications for structural steel for bridges be amended by

lowering the allowable limit for phosphorus in acid open-hearth steel from 0.08 to 0.06 per cent.

The Committee further recommends that the present standard specifications for Bessemer steel rails be replaced by the proposed revised specifications for Bessemer, and the proposed new specifications for open-hearth steel rails, appended to this report.

All of the recommendations embodied in this report have been adopted with practical unanimity by letter ballot of the Committee.

Respectfully submitted on behalf of the Committee,

WM. R. WEBSTER,
Chairman.

EDGAR MARBURG,
Secretary.

NOTE.—The recommendations regarding the above amendments were adopted by letter ballot on August 16, 1909, and the specifications as amended follow this report.—ED.

[For Discussion of this report, see page 70.]

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR BRIDGES.

ADOPTED AUGUST 16, 1909.

1. Steel shall be made by the open-hearth process. **Manufacture.**
2. The chemical and physical properties shall conform to **Chemical**
the following limits: **Composition.**

Elements Considered.	Structural Steel.	Rivet Steel.	Steel Castings
Phosphorus, Max. { Basic Acid	0.04 per cent. 0.06 "	0.04 per cent. 0.04 "	0.05 per cent. 0.08 "
Sulphur, Max.	0.05 "	0.04 "	0.05 "
Ult. tensile strength . . Pounds per sq. in. . . .	Desired. 60,000	Desired 50,000	Not less than 65,000
Elong.: Min. per cent. in 8 in. (Fig. 1)	{ 1,500,000* Ult. tens. str.	1,500,000 Ult. tens. str.	
Elong.: Min. per cent. in 2 in. (Fig. 2)	22	18	
Character of fracture .	Silky	Silky	Silky or fine granular.
Cold bend without fracture	180 degrees flat†	180 degrees flat‡	90 degrees. d = 3t

* See par. 11.

† See par. 12, 13 and 14.

‡ See par. 15.

The yield point, as indicated by the drop of beam, shall be recorded in the test reports.

3. If the ultimate strength varies more than 4,000 lbs. from **Retests.**
that desired, a retest may be made, at the discretion of the inspector, on the same gauge, which, to be acceptable, shall be within 5,000 lbs. of the desired ultimate.

Chemical
Determination.

4. Chemical determinations of the percentages of carbon, phosphorus, sulphur and manganese shall be made by the manufacturer from a test ingot taken at the time of the pouring of each melt of steel and a correct copy of such analysis shall be furnished to the engineer or his inspector. Check analyses shall be made from finished material, if called for by the purchaser, in which case an excess of 25 per cent. above the required limits will be allowed.

Plates, Shapes
and Bars.

5. Specimens for tensile and bending tests for plates, shapes and bars shall be made by cutting coupons from the finished pro-

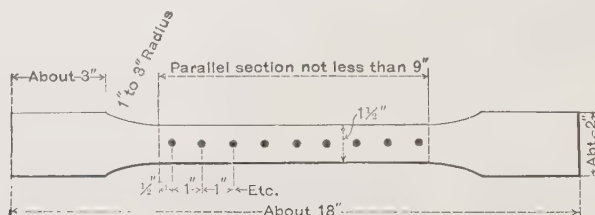


FIG. 1.

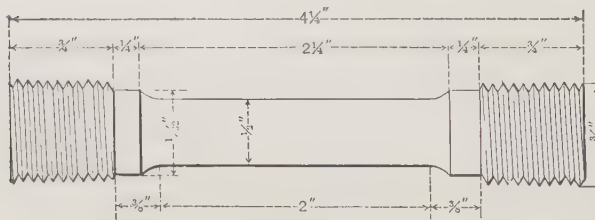


FIG. 2.

duct, which shall have both faces rolled and both edges milled to the form shown by Fig. 1; or with both edges parallel; or they may be turned to a diameter of $\frac{3}{4}$ inch for a length of at least 9 inches, with enlarged ends.

Rivets.

6. Rivet rods shall be tested as rolled.

Pins and Rollers.

7. Specimens shall be cut from the finished rolled or forged bar in such manner that the center of the specimen shall be 1 inch from the surface of the bar. The specimen for tensile test shall be turned to the form shown by Fig. 2. The specimen for bending test shall be 1 inch by $\frac{1}{2}$ inch in section.

Steel Castings.

8. The number of tests will depend on the character and importance of the castings. Specimens shall be cut cold from

coupons molded and cast on some portion of one or more castings from each melt or from the sink-heads, if the heads are of sufficient size. The coupon or sink-head, so used, shall be annealed with the casting before it is cut off. Test specimens to be of the form prescribed for pins and rollers.

9. Material which is to be used without annealing or further treatment shall be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimens for tensile tests representing such material shall be cut from properly annealed or similarly treated short lengths of the full section of the bar. Conditions for Tests.

10. At least one tensile and one bending test shall be made from each melt of steel as rolled. In case steel differing $\frac{3}{8}$ inch and more in thickness is rolled from one melt, a test shall be made from the thickest and thinnest material rolled. Number of Tests.

11. For material less than $\frac{5}{16}$ inch and more than $\frac{3}{4}$ inch in thickness the following modifications will be allowed in the requirements for elongation: Elongation.

(a) For each $\frac{1}{16}$ inch in thickness below $\frac{5}{16}$ inch, a deduction of $2\frac{1}{2}$ will be allowed from the specified percentage.

(b) For each $\frac{1}{8}$ inch in thickness above $\frac{3}{4}$ inch, a deduction of 1 will be allowed from the specified percentage.

12. Bending tests may be made by pressure or by blows. Bending Tests.
Plates, shapes and bars less than 1 inch thick shall bend as called for in Paragraph 2.

13. Full-sized material for eye-bars and other steel 1 inch thick and over, tested as rolled, shall bend cold 180° around a pin the diameter of which is equal to twice the thickness of the bar, without fracture on the outside of bend. Full-sized Bends.

14. Angles $\frac{3}{4}$ inch and less in thickness shall open flat, and angles $\frac{1}{2}$ inch and less in thickness shall bend shut, cold, under blows of a hammer, without sign of fracture. This test will be made only when required by the inspector. Tests for Angles.

15. Rivet steel, when nicked and bent around a bar of the same diameter as the rivet rod, shall give a gradual break and a fine, silky, uniform fracture. Tests on Rivet Steel.

16. Finished material shall be free from injurious seams, flaws, cracks, defective edges, or other defects, and have a smooth Finish.

uniform, workmanlike finish. Plates 36 inches in width and under shall have rolled edges.

Marking. 17. Every finished piece of steel shall have the melt number and the name of the manufacturer stamped or rolled upon it. Steel for pins and rollers shall be stamped on the end. Rivet and lattice steel and other small parts may be bundled with the above marks on an attached metal tag.

Rejections. 18. Material which, subsequent to the above tests at the mills and its acceptance there, develops weak spots, brittleness, cracks or other imperfections, or is found to have injurious defects, will be rejected at the shop and shall be replaced by the manufacturer at his own cost.

Permissible Variations. 19. A variation in cross-section or weight of each piece of steel of more than $2\frac{1}{2}$ per cent. from that specified will be sufficient cause for rejection, except in case of sheared plates, which will be covered by the following permissible variations, which are to apply to single plates.

WHEN ORDERED TO WEIGHT.

Plates $12\frac{1}{2}$ pounds per square foot or heavier:

- (c) Up to 100 inches wide, $2\frac{1}{2}$ per cent. above or below the prescribed weight.
- (d) 100 inches wide and over, 5 per cent. above or below.

Plates under $12\frac{1}{2}$ pounds per square foot:

- (e) Up to 75 inches wide, $2\frac{1}{2}$ per cent. above or below.
- (f) 75 inches and up to 100 inches wide, 5 per cent. above or 3 per cent. below.
- (g) 100 inches wide and over, 10 per cent. above or 3 per cent. below.

WHEN ORDERED TO GAUGE.

Plates will be accepted if they measure not more than 0.01 inch below the ordered thickness.

An excess over the nominal weight corresponding to the dimensions on the order, will be allowed for each plate, if not more than that shown in the following tables, one cubic inch of rolled steel being assumed to weigh 0.2833 pound.

Plates $\frac{1}{4}$ inch and over in thickness.

Thickness Ordered. Inches.	Nominal Weights. Lbs.	Width of Plate.			
		Up to 75 in.	75 in. and up to 100 in.	100 in. and up to 115 in.	Over 115 in.
1-4	10.20	10 per cent.	14 per cent.	18 per cent.	.....
5-16	12.75	8 " "	12 " "	16 " "	.....
5-8	15.30	7 " "	10 " "	13 " "	17 per cent.
7-16	17.85	6 " "	8 " "	10 " "	13 " "
1-2	20.40	5 " "	7 " "	9 " "	12 " "
9-16	22.95	4½ " "	6½ " "	8½ " "	11 " "
5-8	25.50	4 " "	6 " "	8 " "	10 " "
Over 5-8	.....	3½ " "	5 " "	6½ " "	9 " "

Plates under $\frac{1}{4}$ inch in thickness.

Thickness Ordered. Inches.	Nominal Weights. Lbs. per sq. ft.	Width of Plate.		
		Up to 50 in.	50 in. and up to 70 in.	Over 70 in.
1-8 up to 5-32	5.10 to 6.37	10 per cent.	15 per cent.	20 per cent.
5-32 " 3-16	6.37 " 7.65	8½ " "	12½ " "	17 " "
3-16 " 1-4	7.65 " 10.20	7 " "	10 " "	15 " "

20. The purchaser shall be furnished complete copies of mill orders, and no material shall be rolled, nor work done, before the purchaser has been notified where the orders have been placed, so that he may arrange for the inspection.

Inspection and Testing.

21. The manufacturer shall furnish all facilities for inspecting and testing the weight and quality of all material at the mill where it is manufactured. He shall furnish a suitable testing machine for testing the specimens, as well as prepare the pieces for the machine, free of cost.

22. When an inspector is furnished by the purchaser to inspect material at the mills, he shall have full access, at all times, to all parts of mills where material to be inspected by him is being manufactured.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR SHIPS.

ADOPTED AUGUST 16, 1909.

- Manufacture.** 1. Steel shall be made by the open-hearth process.
- Chemical and Physical Properties.** 2. The chemical and physical properties shall conform to the following limits:

Properties Considered.	Structural Steel.	Rivet Steel.	Steel Castings.
Phosphorus, { Basic max. { Acid	0.04 per cent. 0.06 "	0.04 per cent. 0.06 "	0.05 per cent. 0.08 "
Sulphur, max.....	.....	0.05 "	.....
Ult. tensile strength, pounds per sq. in...	55,000-65,000	48,000-58,000	60,000 minimum
Yield point.	$\frac{1}{2}$ Ult. tens. str.	$\frac{1}{2}$ Ult. tens. str.	$\frac{1}{2}$ Ult. tens. str.
Elong., min. per cent. in 8 in. (Fig. 1) ...	{ 1,500,000 Ult. tens. str.	1,500,000 Ult. tens. str.	.....
Elong., min. per cent. in 2 in. (Fig. 2) ...	.....	.....	18
Character of fracture	Silky	Silky	{ Silky or fine granular.
Cold bend without fracture	180° flat	180° flat	{ 90° d = 3t.

For the purposes of these specifications, the yield point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine. **Yield Point.**

3. In order to determine if the material conforms to the chemical limitations prescribed in Paragraph 2 herein, analysis shall be made by the manufacturer from a test ingot taken at the time of the pouring of each melt of steel, and a correct copy of such analysis shall be furnished to the engineer or his inspector. A check analysis may be made by the purchaser or his representative if desired, in which case an excess of 25 per cent. above the required limits will be allowed. **Chemical Determinations.**

4. Specimens for tensile and bending tests for structural and rivet steel shall be made by cutting coupons from the finished **Form of Specimens.**

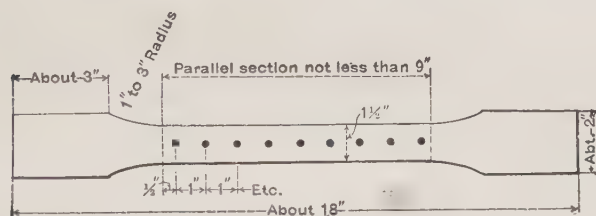


FIG. 1.

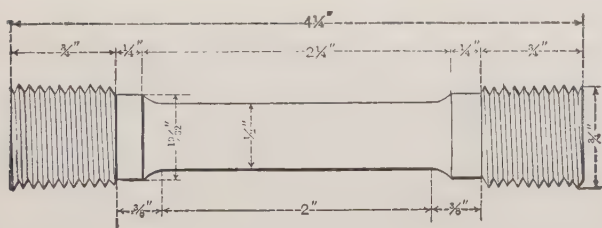


FIG. 2.

product, which shall have both faces rolled and both edges milled to the form shown by Fig. 1; or with both edges parallel; or they may be turned to a diameter of $\frac{3}{4}$ inch for a length of at least 9 inches, with enlarged ends.

(a) Rivet rounds and small rolled bars shall be tested as rolled.

5. The number of tests will depend on the character and importance of the castings. Specimens shall be cut cold from **Steel Castings.**

coupons molded and cast on some portion of one or more castings from each melt or from the sink-heads, if the heads are of sufficient size. The coupon or sink-head so used shall be annealed with the casting before it is cut off. Test specimens shall be of the form shown by Fig. 2.

Annealed Specimens.

6. Material which is to be used without annealing or further treatment shall be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimens for tensile tests, representing such material, shall be cut from properly annealed or similarly treated short lengths of the full section of the bar.

Number of Tests.

7. At least one tensile and one bending test shall be made from each melt of steel as rolled. In case steel differing $\frac{3}{8}$ inch and more in thickness is rolled from one melt, a test shall be made from the thickest and thinnest material rolled. Should either of these test specimens develop flaws, or should the tensile test specimen break outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor. In case a tensile test specimen does not meet the specifications, additional tests may be made.

Modifications in Elongation for Thin and Thick Material.

8. For material less than $\frac{5}{8}$ inch and more than $\frac{3}{4}$ inch in thickness, the following modifications will be allowed in the requirements for elongation:

(b) For each $\frac{1}{8}$ inch in thickness below $\frac{5}{8}$ inch, a deduction of $2\frac{1}{2}$ will be allowed from the specified percentage.

(c) For each $\frac{1}{8}$ inch in thickness above $\frac{3}{4}$ inch, a deduction of 1 will be allowed from the specified percentage.

Bending Tests.

9. Plates, shapes and bars less than $\frac{3}{4}$ inch thick shall bend as called for in Paragraph 2.

(d) Steel $\frac{3}{4}$ inch to $1\frac{1}{4}$ inches thick, inclusive, tested as rolled, shall bend cold 180° around a pin the diameter of which is equal to one and one-half times the thickness of the bar, without fracture on the outside of bend.

(e) Steel over $1\frac{1}{4}$ inches thick, tested as rolled, shall bend cold 180° around a pin the diameter of which is equal to twice the thickness of the bar, without fracture on the outside of bend.

(f) Bending tests may be made by pressure or by blows.

Tests on Angles.

10. Angles $\frac{3}{4}$ inch and less in thickness shall open flat, and angles $\frac{1}{2}$ inch and less in thickness shall bend shut, cold, under

blows of a hammer, without sign of fracture. This test will be made only when required by the inspector.

11. Finished material shall be free from injurious seams, flaws, cracks; defective edges, or other defects, and shall have a smooth, uniform, workmanlike finish. **Finish.**

12. Test specimens and every finished piece of steel shall be stamped with the melt number, except that small pieces may be shipped in bundles securely wired together, with the melt number on a metal tag attached. **Marking.**

13. A variation in cross-section or weight of each piece of steel of more than $2\frac{1}{2}$ per cent. from that specified will be sufficient cause for rejection, except in case of sheared plates, which will be covered by the following permissible variations, which are to apply to single plates. **Variation in Weight.**

WHEN ORDERED TO WEIGHT.

Plates $12\frac{1}{2}$ pounds per square foot or heavier:

- (g) Up to 100 inches wide, $2\frac{1}{2}$ per cent. above or below the prescribed weight.
- (h) 100 inches wide and over, 5 per cent. above or below.

Plates under $12\frac{1}{2}$ pounds per square foot:

- (i) Up to 75 inches wide, $2\frac{1}{2}$ per cent. above or below.
75 inches and up to 100 inches wide, 5 per cent. above or 3 per cent. below.
- (j) 100 inches wide and over, 10 per cent. above or 3 per cent. below.

WHEN ORDERED TO GAUGE.

Plates will be accepted if they measure not more than 0.01 inch below the ordered thickness.

An excess over the nominal weight corresponding to the dimensions on the order will be allowed for each plate, if not more than that shown in the following tables, one cubic inch of rolled steel being assumed to weigh 0.2833 pound.

Plates $\frac{1}{4}$ inch and over in thickness.

Thickness Ordered. Inches.	Nominal Weights. Lbs. per sq. ft.	Width of Plate.			
		Up to 75 ins.	75 ins. and up to 100 ins.	100 ins. and up to 115 ins.	Over 115 ins.
1-4	10.20	10 per cent.	14 per cent.	18 per cent.	
5-16	12.75	8 "	12 "	16 "	
3-8	15.30	7 "	10 "	13 "	17 per cent.
7-16	17.85	6 "	8 "	10 "	13 "
1-2	20.40	5 "	7 "	9 "	12 "
9-16	22.95	4 $\frac{1}{2}$ "	6 $\frac{1}{2}$ "	8 $\frac{1}{2}$ "	11 "
5-8	25.50	4 "	6 "	8 "	10 "
Over 5-8	.....	3 $\frac{1}{2}$ "	5 "	6 $\frac{1}{2}$ "	9 "

Plates under $\frac{1}{4}$ inch in thickness.

Thickness Ordered. Inches.	Nominal Weights. Lbs. per sq. ft.	Width of Plate.		
		Up to 50 ins.	50 ins. and up to 70 ins.	Over 70 ins.
1-8 up to 5-32	5.10 to 6.37	10 per cent.	15 per cent.	20 per cent.
5-32 " 3-16	6.37 to 7.65	8 $\frac{1}{2}$ "	12 $\frac{1}{2}$ "	17 "
3-16 " 1-4	7.65 to 10.20	7 "	10 "	15 "

Inspection. 14. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications.

The manufacturer shall furnish a suitable testing machine for testing the specimens, as well as prepare the pieces for the machine, free of cost.

All tests and inspections shall be made at the place of manufacture, prior to shipment.

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STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR BUILDINGS.

ADOPTED AUGUST 16, 1909.

1. Structural steel may be made by either the open-hearth or **Manufacture,** Bessemer process.

Rivet steel and plate or angle material over $\frac{3}{4}$ inch thick, which is to be punched, shall be made by the open-hearth process.

2. The chemical and physical properties shall conform to the following limits: **Chemical and Physical Properties.**

Properties Considered.	Structural Steel.	Rivet Steel, Open Hearth.
Phosphorus, max., Bessemer.....	0.10 per cent.	
Phosphorus, max., open hearth....	0.06 "	0.06 per cent.
Ult. tensile strength, pounds per sq. in.....	55,000-65,000	48,000-58,000
Yield point	$\frac{1}{2}$ Ult. tens. str.	$\frac{1}{2}$ Ult. tens. str.
Elongation, min. per cent. in 8 ins., (Fig. 1).....	$\frac{1,400,000^*}{\text{Ult. tens. str.}}$	$\frac{1,400,000}{\text{Ult. tens. str.}}$
Character of fracture.....	Silky	Silky
Cold bend without fracture.....	180° to diameter of 1 thickness	180° flat

* See paragraph 7.

For the purposes of these specifications, the yield point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

**Chemical
Determinations.**

3. In order to determine if the material conforms to the chemical limitations prescribed in Paragraph 2 herein, analysis shall be made by the manufacturer from a test ingot taken at the time of the pouring of each melt or blow of steel, and a correct copy of such analysis shall be furnished to the engineer or his inspector.

**Form of
Specimens.**

4. Specimens for tensile and bending tests shall be made by cutting coupons from the finished product, which shall have both faces rolled and both edges milled to the form shown by Fig. 1; or with both edges parallel; or they may be turned to a diameter of $\frac{3}{4}$ inch for a length of at least 9 inches, with enlarged ends.

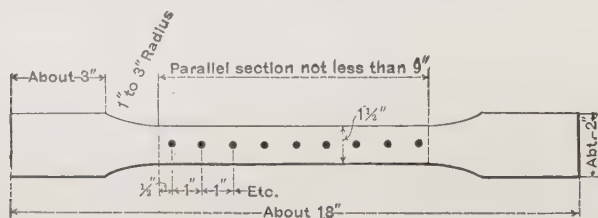


FIG. 1.

(a) For material more than $\frac{3}{4}$ inch thick the bending test specimen may be 1 inch by $\frac{1}{2}$ inch in section.

(b) Rivet rounds and small rolled bars shall be tested as rolled.

**Annealed
Specimens.**

5. Material which is to be used without annealing or further treatment shall be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimens for tensile tests, representing such material, shall be cut from properly annealed or similarly treated short lengths of the full section of the bar.

Number of Tests.

6. At least one tensile and one bending test shall be made from each melt or blow of steel as rolled. In case steel differing $\frac{3}{8}$ inch and more in thickness is rolled from one melt or blow, a test shall be made from the thickest and thinnest material rolled. Should either of these test specimens develop flaws, or should the tensile test specimen break outside of the middle third of its gauged length, it may be discarded and another test specimen

substituted therefor. In case a tensile test specimen does not meet the specification, additional tests may be made.

(c) The bending test may be made by pressure or by blows.

7. For material less than $\frac{5}{16}$ inch and more than $\frac{3}{4}$ inch in thickness, the following modifications shall be made in the requirements for elongation: Modifications in Elongation for Thin and Thick Material.

(d) For each increase of $\frac{1}{8}$ inch in thickness above $\frac{3}{4}$ inch, a deduction of 1 shall be made from the specified percentage of elongation.

(e) For each decrease of $\frac{1}{16}$ inch in thickness below $\frac{5}{16}$ inch, a deduction of $2\frac{1}{2}$ shall be made from the specified percentage of elongation.

(f) For pins, the required percentage of elongation shall be 5 less than that specified in Paragraph 2, as determined on a test specimen, the center of which shall be 1 inch from the surface.

8. Finished material must be free from injurious seams, flaws, Finish. or cracks, and have a workmanlike finish.

9. Test specimens and every finished piece of steel shall be stamped with melt or blow number, except that small pieces may be shipped in bundles securely wired together, with the melt or blow number on a metal tag attached. Branding.

10. A variation in cross-section or weight of each piece of steel of more than $2\frac{1}{2}$ per cent. from that specified will be sufficient cause for rejection, except in case of sheared plates, which will be covered by the following permissible variations, which are to apply to single plates. Variation in Weight.

WHEN ORDERED TO WEIGHT.

Plates $12\frac{1}{2}$ pounds per square foot or heavier:

(g) Up to 100 inches wide, $2\frac{1}{2}$ per cent. above or below the prescribed weight.

(h) 100 inches wide and over, 5 per cent. above or below.

Plates under $12\frac{1}{2}$ pounds per square foot:

(i) Up to 75 inches wide, $2\frac{1}{2}$ per cent. above or below.

75 inches and up to 100 inches wide, 5 per cent. above or 3 per cent. below.

(j) 100 inches wide and over, 10 per cent. above or 3 per cent. below.

WHEN ORDERED TO GAUGE.

Plates will be accepted if they measure not more than 0.01 inch below the ordered thickness.

An excess over the nominal weight corresponding to the dimensions on the order will be allowed for each plate, if not more than that shown in the following tables, one cubic inch of rolled steel being assumed to weigh 0.2833 pound.

Plates $\frac{1}{4}$ inch and over in thickness.

Thickness Ordered. Inches.	Nominal Weights. Lbs. per sq. ft.	Width of Plate.			
		Up to 75 ins.	75 ins. and up to 100 ins.	100 ins. and up to 115 ins.	Over 115 ins.
1-4	10.20	10 per cent.	14 per cent.	18 per cent.	
5-16	12.75	8 "	12 "	16 "	
3-8	15.30	7 "	10 "	13 "	17 per cent.
7-16	17.85	6 "	8 "	10 "	13 "
1-2	20.40	5 "	7 "	9 "	12 "
9-16	22.95	4 $\frac{1}{2}$ "	6 $\frac{1}{2}$ "	8 $\frac{1}{2}$ "	11 "
5-8	25.50	4 "	6 "	8 "	10 "
Over 5-8	.....	3 $\frac{1}{2}$ "	5 "	6 $\frac{1}{2}$ "	9 "

Plates under $\frac{1}{4}$ inch in thickness.

Thickness Ordered. Inches.	Nominal Weights. Lbs. per sq. ft.	Width of Plate.		
		Up to 50 ins.	50 ins. and up to 70 ins.	Over 70 ins.
1-8 up to 5-32	5.10 to 6.37	10 per cent.	15 per cent.	20 per cent.
5-32 " 3-16	6.37 to 7.65	8 $\frac{1}{2}$ "	12 $\frac{1}{2}$ "	17 "
3-16 " 1-4	7.65 to 10.20	7 "	10 "	15 "

Inspection. 11. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications.

All tests and inspections shall be made at the place of manufacture, prior to shipment.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

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STANDARD SPECIFICATIONS FOR OPEN-HEARTH BOILER PLATE AND RIVET STEEL.

ADOPTED AUGUST 16, 1909.

1. Steel shall be made by the open-hearth process.
 2. There shall be three classes of open-hearth boiler plate steel; namely, flange steel, fire box steel and extra soft steel, which shall conform to the following limits in chemical and physical properties:

Process of
 Manufacture.
 Chemical and
 Physical
 Properties.

	Flange Steel.	Fire Box Steel.	Extra Soft Steel.
Phosphorus shall not exceed	{ Acid 0.06 per cent. Basic 0.04	{ Acid 0.04 per cent. Basic 0.03	} 0.04 per cent.
Sulphur shall not exceed	0.05 "	0.04 "	0.04 "
Manganese.	0.30 to 0.60 per cent.	0.30 to 0.50 per cent.	0.30 to 0.50 per cent.
Ult. tensile strength, pounds per sq. in..	55,000-65,000	52,000-62,000	45,000-55,000
Yield point, in pounds per sq. in., shall not be less than.....	$\frac{1}{2}$ Ult. tens. str.	$\frac{1}{2}$ Ult. tens. str.	$\frac{1}{2}$ Ult. tens. str.
Elongation, per cent. in 8 in. shall not be less than	$\frac{1,500,000}{\text{Ult. tens. str.}}$	$\frac{1,500,000}{\text{Ult. tens. str.}}$	$\frac{1,500,000}{\text{Ult. tens. str.}}$ (but need not exceed 30 per cent.)
Cold bend	} 180° flat.	} 180° flat.	} 180° flat.
Quench bend			

Yield Point.

(a) For the purposes of these specifications, the yield point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

Boiler Rivet Steel.

3. Steel for boiler rivets shall be of the extra soft class, as specified in Paragraph 2.

Modifications in Elongation for Thin and Thick Material.

4. For material less than $\frac{5}{16}$ inch and more than $\frac{3}{4}$ inch in thickness, the following modifications shall be made in the requirements for elongation:

(b) For each increase of $\frac{1}{8}$ inch in thickness above $\frac{3}{4}$ inch, a deduction of 1 shall be made from the specified percentage of elongation.

(c) For each decrease of $\frac{1}{16}$ inch in thickness below $\frac{5}{16}$ inch, a deduction of $2\frac{1}{2}$ shall be made from the specified percentage of elongation.

Chemical Determinations.

5. In order to determine if the material conforms to the chemical limitations prescribed in Paragraph 2 herein, analysis shall be made by the manufacturer from a test ingot taken at the time of the pouring of each melt of steel, and a correct copy of such analysis shall be furnished to the engineer or his inspector. A check analysis may be made by the purchaser or his representative, from a broken tensile test specimen representing each heat of flange or extra soft steel on an order, and for each plate as rolled of fire box steel, in which cases an excess of 25 per cent. above the required limits in phosphorus and sulphur will be allowed.

Test Specimen for Tensile Test.

6. The standard tensile test specimen of 8-inch gauged length shall be used to determine the physical properties specified in Paragraphs 2 and 3. The standard shape of the tensile test specimen for sheared plates shall be as shown in Fig. 1.

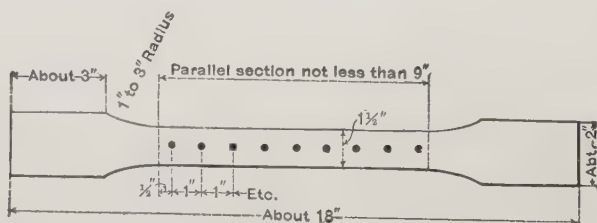


FIG. 1.

For other material the tensile test specimen may be the same as for sheared plates, or it may be planed or turned parallel

throughout its entire length and in all cases where possible two opposite sides of the test specimens shall be the rolled surfaces.

Rivet rounds and small rolled bars shall be tested of full size as rolled.

7. The bending test specimen shall be $1\frac{1}{2}$ inches wide, if possible, and for all material $\frac{3}{4}$ inch or less in thickness the test specimen shall have the natural rolled surface on two opposite sides; but for material more than $\frac{3}{4}$ inch thick, the bending test specimen may be $\frac{1}{2}$ inch thick. The sheared edges of bending test specimens shall be milled or planed. The bending test may be made by pressure or by blows. The cold bending test shall be made on the material in the condition in which it is to be used, and prior to the quenched bending test, the specimen shall be heated to a light cherry red as seen in the dark and quenched in water, the temperature of which is between 80° and 90° Fahrenheit.

Test Specimens
for Bending
Tests.

Rivet rounds shall be tested of full size as rolled.

8. For fire box steel a sample taken from a broken tensile test specimen shall not show any single seam or cavity more than $\frac{1}{4}$ inch long, in either of the three fractures obtained on the test for homogeneity, as described below:

Homogeneity
Tests.

(d) The homogeneity test is made as follows: A portion of the broken tensile test specimen is either nicked with a chisel or grooved on a machine, transversely about $\frac{1}{16}$ inch deep in three places about 2 inches apart. The first groove should be made on one side, 2 inches from the square end of the specimen; the second, 2 inches from it on the opposite side; and the third, 2 inches from the last, and on the opposite side from it. The test specimen is then put in a vise, with the first groove about $\frac{1}{4}$ inch above the jaws, care being taken to hold it firmly. The projecting end of the test specimen is then broken off by means of a hammer, a number of light blows being used, and the bending being away from the groove. The specimen is broken at the other two grooves in the same way. The object of this treatment is to open and render visible to the eye any seams due to failure to weld up, or to foreign interposed matter, or cavities due to gas bubbles in the ingot. After rupture, one side of each fracture is examined, a pocket lens being used if necessary, and the length of the seams and cavities is determined.

Number of Tests.

9. Three test pieces shall be furnished from each plate as it is rolled; one for tension, one for cold bending and one for quench bending test. For rivet rods, two tensile test specimens and two cold bending and two quench bending test specimens shall be furnished from each melt. In case any one of these develops flaws, or should a tensile test specimen break outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor.

Permissible Variations.

10. A variation in cross-section or weight of each piece of steel of more than $2\frac{1}{2}$ per cent. from that specified will be sufficient cause for rejection, except in case of sheared plates, which will be covered by the following permissible variations, which are to apply to single plates.

WHEN ORDERED TO WEIGHT.

Plates $12\frac{1}{2}$ pounds per square foot or heavier:

- (e) Up to 100 inches wide, $2\frac{1}{2}$ per cent. above or below the prescribed weight.
- (f) 100 inches wide and over, 5 per cent. above or below.

Plates under $12\frac{1}{2}$ pounds per square foot:

- (g) Up to 75 inches wide, $2\frac{1}{2}$ per cent. above or below.
- (h) 75 inches and up to 100 inches wide, 5 per cent. above or 3 per cent. below.
- (i) 100 inches wide and over, 10 per cent. above or 3 per cent. below.

WHEN ORDERED TO GAUGE.

Plates will be accepted if they measure not more than 0.01 inch below the ordered thickness.

An excess over the nominal weight corresponding to the dimensions on the order will be allowed for each plate, if not more than that shown in the following tables, one cubic inch of rolled steel being assumed to weigh 0.2833 pound.

Plates $\frac{1}{4}$ inch and over in thickness.

Thickness Ordered. Inches.	Nominal Weights. Lbs. per sq. ft.	Width of Plate.			
		Up to 75 ins.	75 ins. and up to 100 ins.	100 ins. and up to 115 ins.	Over 115 ins.
1-4	10.20	10 per cent.	14 per cent.	18 per cent.	
5-16	12.75	8 "	12 "	16 "	
3-8	15.30	7 "	10 "	13 "	17 per cent.
7-16	17.85	6 "	8 "	10 "	13 "
1-2	20.40	5 "	7 "	9 "	12 "
9-16	22.95	4½ "	6½ "	8½ "	11 "
5-8	25.50	4 "	6 "	8 "	10 "
Over 5-8	.....	3½ "	5 "	6½ "	9 "

Plates under $\frac{1}{4}$ inch in thickness.

Thickness Ordered. Inches.	Nominal Weights. Lbs per sq. ft.	Width of Plate.		
		Up to 50 ins.	50 ins. and up to 70 ins.	Over 70 ins.
1-8 up to 5-32	5.10 to 6.37	10 per cent.	15 per cent.	20 per cent.
5-32 " 3-16	6.37 to 7.65	8½ "	12½ "	17 "
3-16 " 1-4	7.65 to 10.20	7 "	10 "	15 "

11. Each plate shall be distinctly stamped with its heat or **Branding**, slab number, and with the name of the manufacturer, grade, and lowest tensile strength specified. Each test specimen shall be distinctly stamped with the heat or slab number which it represents.

Rivet steel may be shipped in securely fastened bundles with the melt number stamped on a metal tag attached.

12. All finished material shall be free from injurious surface **Finish**, defects and laminations, and must have a workmanlike finish.

13. The inspector representing the purchaser shall have all **Inspection**, reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR STEEL SPLICE BARS.

ADOPTED AUGUST 16, 1909.

Process of Manufacture.

1. Steel for splice bars may be made by the Bessemer or open-hearth process.

Phosphorus Limit.

2. The phosphorus in steel for splice bars shall not exceed 0.10 per cent.

Tensile Tests.

3. Splice bar steel shall conform to the following physical qualities:

Tensile strength, pounds per square inch... 54,000 to 64,000

Yield point, pounds per square inch..... $\frac{1}{2}$ T. S.

Elongation, per cent. in eight inches shall
not be less than.....

25

Bending Tests.

4. (a) A test specimen cut from the head of the splice bar shall bend 180° flat on itself without fracture on the outside of the bent portion.

(b) If preferred the bending tests may be made on an unpunched splice bar, which, if necessary, shall be first flattened, and shall then be bent 180° flat on itself without fracture on the outside of the bent portion.

Test Specimen for Tensile Test.

5. A test specimen of 8-inch gauged length, cut from the rolled splice bar, shall be used to determine the physical properties specified in Paragraph 3.

6. One tensile test specimen shall be taken from the rolled splice bars of each blow or melt, but in case this develops flaws, or breaks outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor. **Number of Tensile Tests.**

7. One test specimen cut from the head of the splice bar shall be taken from a rolled bar of each blow or melt, or if preferred the bending test may be made on an unpunched splice bar, which, if necessary, shall be flattened before testing. The bending test may be made by pressure or by blows. **Test Specimen for Bending.**

8. For the purposes of these specifications, the yield point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine. **Yield Point.**

9. In order to determine if the material conforms to the chemical limitations prescribed in Paragraph 2 herein, analysis shall be made of drillings taken from a small test ingot. **Sample for Chemical Analysis.**

10. All splice bars shall be smoothly rolled and true to templet. The bars shall be sheared accurately to length and free from fins or cracks, and shall perfectly fit the rails for which they are intended. The punching and notching shall accurately conform in every respect to the drawing and dimensions furnished. **Finish.**

11. The name of the maker and the year of manufacture shall be rolled in raised letters on the side of the splice bar. **Branding.**

12. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment. **Inspection.**

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

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STANDARD SPECIFICATIONS FOR STEEL TIRES.

ADOPTED AUGUST 16, 1909

Material.

1. Steel for tires shall be made by the open-hearth process.

Classes.

2. There will be three classes of tires for the different classes of service as follows:

(a) Driving tires for passenger engines.

(b) Driving tires for freight engines and tires for engine-truck, tender-truck, trailer and car wheels.

(c) Driving tires for switching engines.

**Chemical
Composition.**

3. The steel for the three classes of service shall conform to the following limits in chemical composition:

Manganese shall not exceed 0.75 per cent.

Silicon shall not exceed 0.35 " "

Phosphorus shall not exceed 0.05 " "

Sulphur shall not exceed 0.05 " "

**Samples for
Chemical
Analyses.**

4. Drillings from a small test ingot cast with the heat or turnings from a tensile specimen or turnings from a tire (where tires are machined at the works of the manufacturer) shall be used to determine whether the chemical composition of the heat is within the limits specified in Paragraph 3.

When samples for chemical analyses are taken from the finished material, a variation of 25 per cent. excess in phosphorus and sulphur over the limits specified in Paragraph 3 will be allowed.

5. When required, the purchaser or his representative shall be furnished an analysis of each heat from which tires are made. **Analyses
Furnished.**

6. The steel for the different classes of service shall meet the following minimum physical requirements: **Physical
Properties.**

Class.	Tensile strength, lbs. per sq. in.	Elongation, per cent. in 2 ins.	Reduction of area, per cent.
(a)	105,000	12	16
(b)	115,000	10	14
(c)	125,000	8	12

7. Samples for physical tests shall be taken from a test bar from an ingot of each heat represented, the ingot to be of such size as to give as nearly as practicable the same amount of work on the test bar as on the tire. **Samples for
Physical Tests.**

8. The standard turned test specimen, as shown by Fig. 1, $\frac{1}{2}$ in. in diameter and 2 ins. gauge length, shall be used to determine the physical properties as specified in Paragraph 6. **Specimen for
Tensile Tests.**

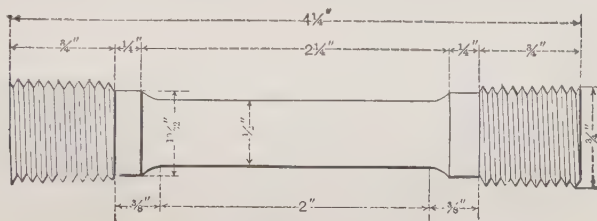


FIG. 1.

9. Should the contract call for a falling-weight test, a test tire from each heat represented shall be selected by the purchaser or his representative, and furnished at his expense provided it meets the requirements. **Falling-weight
Test.**

9a. The test tire shall be placed vertically under the drop in a running position on a solid foundation with an anvil of at least ten tons weight and shall be subjected to successive blows from a tup weighing 2,240 lbs., falling from heights of 10 ft., 15 ft. and 20 ft. and upwards, until the required deflection is obtained as specified in Paragraph 9b.

9b. The test tire shall stand the drop test described in Paragraph 9a. without breaking or cracking and shall show a minimum deflection equal to $D^2 \div (40T^2 + 2D)$, D being the

internal diameter in inches and T the thickness of the tire at center of tread.

9c. When requested, a specimen for the tensile test is to be taken from a tire that has been subjected to a falling-weight test, and it shall be cut cold from the tested tire at the point least affected by the falling-weight test. The tensile test specimen, when cut from a tire that has been subjected to a falling-weight test, shall be cut normal to the radius and parallel to the face.

9d. Should the test tire fail to meet the requirements in any particular, two more test tires shall be selected from the same heat if the manufacturer so desires, and at his expense. Should these two tires fulfill the requirements, the heat shall be accepted.

Finish.

10. Tires must be free from cracks, flaws, seams, or other injurious imperfections. Tires developing such defects while being finished shall be returned to the manufacturer at his expense and replaced free of charge.

Tires (when furnished in the rough) shall conform to drawings with the following tolerances:

- (a) *Height of Flange.*—The height of flange shall not be more than $\frac{3}{32}$ in. over or under the height called for.
- (b) *Width of Flange.*—The width of flange shall not be more than $\frac{1}{16}$ in. over or under the dimensions called for.
- (c) *Throat Radius.*—The throat radius shall not be more than $\frac{1}{8}$ in. greater nor more than $\frac{1}{16}$ in. less than the radius called for.
- (d) *Width of Tire.*—The width of tire shall not be more than $\frac{1}{8}$ in. greater nor more than $\frac{1}{16}$ in. less than the width called for.
- (e) *Inside Diameter.*—The diameter shall not be less than the diameter of the finished tire by more than $\frac{3}{8}$ in.
- (f) *Outside Diameter.*—Tires 33 ins. or less in inside diameter shall be furnished in sets not varying more than $\frac{1}{16}$ in. in outside diameters and not out of round more than $\frac{1}{16}$ in.

Tires over 33 ins. in inside diameter shall be furnished in sets not varying more than $\frac{3}{32}$ in. in outside diameter and not out of round more than $\frac{3}{32}$ in.

Branding.

11. The manufacturer's brand and serial number shall be

stamped on the tire close to the inside edge where the stamping will not be cut off at the last turning. Set numbers shall be stenciled on each tire.

12. The inspector representing the purchaser shall have free **Inspection.** entry to the works of the manufacturer at all times while his contract is being executed. All reasonable facilities shall be afforded to the inspector by the manufacturer to satisfy him that the tires are being furnished in accordance with the specifications. All tests and inspection shall be made at the place of manufacture prior to shipment and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

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INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR BESSEMER STEEL RAILS.

ADOPTED AUGUST 16, 1909.

Process of Manufacture.

1. (a) The entire process of manufacture and testing shall be in accordance with the best current practice, and special care shall be taken to conform to the following instructions:
 - (b) Ingots shall be kept in a vertical position in the pit heating furnaces until ready to be rolled or until the metal in the interior has time to solidify.
 - (c) No bled ingots shall be used.
 - (d) There shall be sheared from the end of the blooms formed from the top of the ingots not less than x per cent.,* and if, from any cause, the steel does not then appear to be solid, the shearing shall continue until it does.

Chemical Composition.

2. Rails of the various weights per yard specified below shall conform to the following limits in chemical composition:

	50 to 60 lbs. Per cent.	61 to 70 lbs. Per cent.	71 to 80 lbs. Per cent.	81 to 90 lbs. Per cent.	91 to 100 lbs. Per cent.
Carbon.....	0.35-0.45	0.35-0.45	0.40-0.50	0.43-0.53	0.45-0.55
Phosphorus, not over.....	0.10	0.10	0.10	0.10	0.10
Silicon, not over.....	0.20	0.20	0.20	0.20	0.20
Manganese.....	0.70-1.00	0.70-1.00	0.75-1.05	0.80-1.10	0.84-1.14

*The percentage of minimum discard in any case to be subject to agreement, and it should be recognized that the higher this percentage the greater will be the cost.

3. The number of passes and speed of train shall be so regulated that on leaving the rolls at the final pass, the temperature of rails of sections 75 lbs. per yard and heavier will not exceed that which requires a shrinkage allowance at the hot saws of $6\frac{7}{16}$ ins. for a 33-ft. 75-lb. rail, with an increase of $\frac{1}{16}$ in. for each increase of 5 lbs. in the weight of the section. **Shrinkage.**

No artificial means of cooling the steel shall be used after the rails leave the rolls, nor shall they be held before sawing for the purpose of reducing their temperature.

4. One drop test may be made on a piece of rail not less than 4 ft. and not more than 6 ft. long, selected from each blow of steel. **Drop Test.**

The rails shall be placed head upward on the supports and the various sections shall be subjected to the following impact tests under a free falling weight:

Weights of rail per yard.	Height of drop in feet.
50 to 60 lbs.	15
61 to 70 lbs.	16
71 to 80 lbs.	16
81 to 90 lbs.	17
91 to 100 lbs.	18

If any rail breaks when subjected to the drop test, two additional tests will be made of other rails from the same blow of steel, and if either of these latter tests fail, all the rails of the blow which they represent will be rejected; but if both of these additional test pieces meet the requirements all the rails of the blow which they represent will be accepted.

The drop-testing machine shall have a tup of 2,000 lbs. weight, the striking face of which shall have a radius of not more than 5 ins., and the test rail shall be placed head upward on solid supports 3 ft. apart. The anvil block shall weigh at least 20,000 lbs., and the supports shall be part of, or firmly secured to, the anvil. The report of the drop test shall state the atmospheric temperature at the time the test was made. The temperature of the test pieces, when tested, shall be not less than 60° F. or greater than 120° F. The testing shall proceed concurrently with the operation of the mill. **Drop-Testing Machine.**

5. Unless otherwise specified, the section of rail shall be the American standard, recommended by the American Society of **Weight and Section.**

Civil Engineers, and shall conform, as accurately as possible, to the templet furnished by the railroad company, consistent with Paragraph 6, relative to specified weight. A variation in height of $\frac{1}{16}$ in. less, or $\frac{1}{8}$ in. greater than the specified height, and $\frac{1}{16}$ in. in width will be permitted.

6. The weight of the rails will be maintained as nearly as possible, after complying with Paragraph 5, to that specified in the contract. A variation of one-half of 1 per cent. for an entire order will be allowed. Rails shall be accepted and paid for according to actual weights.

Length.

7. The standard length of rails shall be 30 or 33 feet. Ten per cent. of the entire order will be accepted in shorter lengths, varying by even feet down to 24 feet. A variation of $\frac{1}{4}$ in. in length from that specified will be allowed.

Both ends of all short-length No. 1 rails shall be painted green.

8. Circular holes for splice bolts shall be drilled in accordance with the specifications of the purchaser. The holes shall accurately conform to the drawing and dimensions furnished, and must be free from burrs.

Finish.

9. Care must be taken in hot-straightening the rails, and it must result in their being left in such a condition that they shall not vary throughout their entire length more than 5 ins. from a straight line in any direction when delivered to the cold-straightening presses. Those which vary beyond that amount, or have short kinks, shall be classed as second quality rails and be so stamped. The distance between supports of rails in the gagging press shall not be less than 42 ins. Rails shall be straight in line and surface when finished—the straightening being done while cold—smooth on head, sawed square at ends, variations to be not more than $\frac{1}{32}$ in., and, prior to shipment, shall have the burr occasioned by the saw cutting removed and the ends made clean. No. 1 rails shall be free from injurious defects and flaws of all kinds.

Branding.

10. The name of the maker, the weight of the rail, and the month and year of manufacture shall be rolled in raised letters on the side of the web, and the number of the heat shall be so stamped on each rail as not to be covered by the splice bars. For rails weighing 70 lbs. per yard or over, a letter shall be stamped on the side of the web to indicate the portion of the ingot from which the rail was rolled.

11. No. 2 rails will be accepted to at least 5 per cent. of the whole order. Rails that possess any injurious defects, or which for any other cause are not suitable for first quality, or No. 1 rails, shall be considered as No. 2 rails; provided, however, that rails which contain any physical defects which impair their strength shall be rejected. The ends of all No. 2 rails shall be painted white in order to distinguish them. Rails rejected under the drop test will not be accepted as No. 2 rails. No. 2 Rails.

12. The manufacturer shall furnish the inspector, daily, with carbon determinations of each blow, and a complete chemical analysis every 24 hours, representing the average of the other elements contained in the steel for each day and night turn. Analyses shall be made on drillings taken from small test ingots, the drillings being taken at a distance of not less than $\frac{1}{4}$ in. beneath the surface of said test ingots. On request of the inspector the manufacturer shall furnish drillings for check analysis. Inspection.

The inspector representing the purchaser shall have free entry to the works of the manufacturer at all times while his contract is being executed, and shall have all reasonable facilities afforded him by the manufacturer to satisfy him that the rails are being made in accordance with the terms of the contract. All tests and inspection shall be made at the place of manufacture prior to shipment, and shall be so conducted as not to unnecessarily interfere with the operation of the mill.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR OPEN-HEARTH STEEL RAILS.

ADOPTED AUGUST 16, 1909.

Process of Manufacture.

1. (a) The entire process of manufacture and testing shall be in accordance with the best current practice, and special care shall be taken to conform to the following instructions:
- (b) Ingots shall be kept in a vertical position in the pit heating furnaces until ready to be rolled or until the metal in the interior has time to solidify.
- (c) No bled ingots shall be used.
- (d) There shall be sheared from the end of the blooms formed from the top of the ingots not less than x per cent.,* and if, from any cause, the steel does not then appear to be solid, the shearing shall continue until it does.

Chemical Composition.

2. Rails of the various weights per yard specified below shall conform to the following limits in chemical composition:

	50 to 60 lbs. Per cent.	61 to 70 lbs. Per cent.	71 to 80 lbs. Per cent.	81 to 90 lbs. Per cent.	91 to 100 lbs. Per cent.
Carbon.....	0.46-0.59	0.46-0.59	0.52-0.65	0.59-0.72	0.62-0.75
Phosphorus, not over.....	0.04	0.04	0.04	0.04	0.04
Silicon, not over.....	0.20	0.20	0.20	0.20	0.20
Manganese.....	0.60-0.90	0.60-0.90	0.60-0.90	0.60-0.90	0.60-0.90

*The percentage of minimum discard in any case to be subject to agreement, and it should be recognized that the higher this percentage the greater will be the cost.

For each decrease of 0.003 per cent. in phosphorus down to 0.03 per cent. phosphorus, an increase of 0.01 per cent. carbon will be accepted.

3. The number of passes and speed of train shall be so regulated that on leaving the rolls at the final pass, the temperature of rails of sections 75 lbs. per yard and heavier will not exceed that which requires a shrinkage allowance at the hot saws of $6\frac{7}{16}$ ins. for a 33-ft. 75-lb. rail, with an increase of $\frac{1}{16}$ in. for each increase of 5 lbs. in the weight of the section. **Shrinkage.**

No artificial means of cooling the steel shall be used after the rails leave the rolls, nor shall they be held before sawing for the purpose of reducing their temperature.

4. One drop test may be made on a piece of rail not less than 4 ft. and not more than 6 ft. long, selected from each heat of steel. **Drop Test.**

The rails shall be placed head upward on the supports and the various sections shall be subjected to the following impact tests under a free falling weight:

Weights of rail per yard.	Height of drop in feet.
50 to 60 lbs.	15
61 to 70 lbs.	16
71 to 80 lbs.	16
81 to 90 lbs.	17
91 to 100 lbs.	18

If any rail breaks when subjected to the drop test, two additional tests will be made of other rails from the same heat of steel, and if either of these latter tests fail, all the rails of the heat which they represent will be rejected; but if both of these additional test pieces meet the requirements all the rails of the heat which they represent will be accepted.

The drop-testing machine shall have a tup of 2,000 lbs. weight, the striking face of which shall have a radius of not more than 5 ins., and the test rail shall be placed head upward on solid supports 3 ft. apart. The anvil block shall weigh at least 20,000 lbs., and the supports shall be part of, or firmly secured to, the anvil. The report of the drop test shall state the atmospheric temperature at the time the test was made. The temperature of the test pieces, when tested, shall be not less than 60° F. or greater than 120° F. The testing shall proceed concurrently with the operation of the mill. **Drop-Testing Machine.**

**Weight and
Section.**

5. Unless otherwise specified, the section of rail shall be the American standard, recommended by the American Society of Civil Engineers, and shall conform, as accurately as possible, to the templet furnished by the railroad company, consistent with Paragraph 6, relative to specified weight. A variation in height of $\frac{1}{64}$ in. less, or $\frac{1}{32}$ in. greater than the specified height, and $\frac{1}{16}$ in. in width will be permitted.

6. The weight of the rails will be maintained as nearly as possible, after complying with Paragraph 5, to that specified in the contract. A variation of one-half of 1 per cent. for an entire order will be allowed. Rails shall be accepted and paid for according to actual weights.

Length.

7. The standard length of rails shall be 30 or 33 feet. Ten per cent. of the entire order will be accepted in shorter lengths, varying by even feet down to 24 feet. A variation of $\frac{1}{4}$ in. in length from that specified will be allowed.

Both ends of all short-length No. 1 rails shall be painted green.

8. Circular holes for splice bolts shall be drilled in accordance with the specifications of the purchaser. The holes shall accurately conform to the drawing and dimensions furnished, and must be free from burrs.

Finish.

9. Care must be taken in hot-straightening the rails, and it must result in their being left in such a condition that they shall not vary throughout their entire length more than 5 ins. from a straight line in any direction when delivered to the cold-straightening presses. Those which vary beyond that amount, or have short kinks, shall be classed as second quality rails and be so stamped. The distance between supports of rails in the gagging press shall not be less than 42 ins. Rails shall be straight in line and surface when finished—the straightening being done while cold—smooth on head, sawed square at ends, variations to be not more than $\frac{1}{32}$ in., and, prior to shipment, shall have the burr occasioned by the saw cutting removed and the ends made clean. No. 1 rails shall be free from injurious defects and flaws of all kinds.

Branding.

10. The name of the maker, the weight of the rail, and the month and year of manufacture shall be rolled in raised letters on the side of the web, and the number of the heat and the letters O. H. (to designate the grade of steel) shall be so stamped on each

rail as not to be covered by the splice bars. For rails weighing 70 lbs. per yard or over, a letter shall be stamped on the side of the web to indicate the portion of the ingot from which the rail was rolled.

11. No. 2 rails will be accepted to at least 5 per cent. of the whole order. RAILS THAT POSSESS ANY INJURIOUS DEFECTS, OR WHICH FOR ANY OTHER CAUSE ARE NOT SUITABLE FOR FIRST QUALITY, OR NO. 1 RAILS, SHALL BE CONSIDERED AS NO. 2 RAILS; PROVIDED, HOWEVER, THAT RAILS WHICH CONTAIN ANY PHYSICAL DEFECTS WHICH IMPAIR THEIR STRENGTH SHALL BE REJECTED. THE ENDS OF ALL NO. 2 RAILS SHALL BE PAINTED WHITE IN ORDER TO DISTINGUISH THEM. RAILS REJECTED UNDER THE DROP TEST WILL NOT BE ACCEPTED AS NO. 2 RAILS. No. 2 Rails.

12. The manufacturer shall furnish the inspector a chemical analysis of each heat of steel covering the elements specified. ANALYSES SHALL BE MADE ON DRILLINGS TAKEN FROM SMALL TEST INGOTS, THE DRILLINGS BEING TAKEN AT A DISTANCE OF NOT LESS THAN $\frac{1}{4}$ IN. BENEATH THE SURFACE OF SAID TEST INGOTS. ON REQUEST OF THE INSPECTOR THE MANUFACTURER SHALL FURNISH DRILLINGS FOR CHECK ANALYSIS. Inspection.

The inspector representing the purchaser shall have free entry to the works of the manufacturer at all times while his contract is being executed, and shall have all reasonable facilities afforded him by the manufacturer to satisfy him that the rails are being made in accordance with the terms of the contract. All tests and inspection shall be made at the place of manufacture prior to shipment, and shall be so conducted as not to unnecessarily interfere with the operation of the mill.

DISCUSSION.

Mr. Woodroffe. MR. G. H. WOODROFFE.—Failures in locomotive boiler shells are few and far between, in comparison with the number of failures of firebox plates, where the steel is subjected to the intense heat and corrosive action of the products of combustion, as well as to severe physical strains. In setting a standard for the material which is to enter into the construction of such an important part of the locomotive, it is imperative that these standards be made as high as possible, in order to insure a grade of material that can be relied upon to a reasonable degree of certainty. It is our belief that the present standard specification for furnace steel does not further this end, in that it does not demand the highest grade of material, either chemically or physically.

Chemical Requirements.—In the first place the sulphur and phosphorus limits of 0.04 per cent. are, in our estimation, too lenient. For example, the steel desired in ours, Baldwin Locomotive Works specifications, is to have a sulphur content of 0.035 per cent. and a phosphorus content of 0.03 per cent. The phosphorus limit we stretch somewhat, but no plate is accepted which shows over 0.035 per cent. in either phosphorus or sulphur, unless the other element is correspondingly low, the maximum figure in any case being 0.037 per cent.

High sulphur, which is oftener found in basic open-hearth steel than high phosphorus, we consider the worse of the two faults, as it is the presence of this element in the steel which makes it subject to burns, to a great extent. It may be too, as Mr. Fay's experiments would indicate, that manganese sulphide streaks are formed, making lines of weakness in the direction of the length of the plate. At all events, the Baldwin Locomotive Works have come to the conclusion, through years of experience, that steel containing more than 0.035 per cent. of sulphur and phosphorus cannot be depended upon.

Physical Requirements.—Even more important than the lower chemical limits, is the need of a better material as regards trans-

verse strength, for the laminations and slag streaks which run parallel to the direction of rolling and which materially weaken the plate, do not affect the longitudinal strength to any great extent, and consequently do not show up until the sheet fails. If the plates were tested transversely as well as longitudinally, such defects and weaknesses would be revealed. Mr. Woodroffe.

With the increase in width of rolled plates, making possible the use of one long, wide plate for the crown and sides, has come an increase in the number of firebox failures. The stresses in the side and crown sheets of a locomotive firebox produced by sudden temperature changes, are a maximum in the direction of the length of the boiler, and constitute a large percentage of the total stresses therein. Within the last three years, about 25 to 30 per cent. of the locomotives built by the Baldwin Locomotive Works have had these three-piece fireboxes. In this construction, the severe and fatiguing stresses referred to above are in the direction of least resistance of the plate, i. e., across rolling, the width of the plate being in the direction of the length of the boiler.

The advantages of such a construction are considerable and warrant its general adoption, but in order to insure safety and reliability, a standard must be set for the transverse strength of the material, and what is more important, we must have the material that will meet these standard requirements. That this, in our opinion, important phase of the question has hitherto been neglected, is shown by the fact that among all specifications of railroad companies and locomotive manufacturers, there is but one in which any mention is made of a transverse test for boiler and firebox steel. This exception, I might say, is the Great Northern Specification No. 16, which has been in existence since 1895.

We had occasion about a year ago to make some tests on firebox sheets which had been cut out on account of transverse failures; these sheets came from some Pacific type engines which had been in service from three to eight months on one of the western roads. Our results showed that while the pieces cut from the sheets in the direction of rolling, fulfilled the requirements, those pieces taken across the direction of rolling fell below the limits, both in the matter of tensile strength and elongation. This difference in quality of the same plate in the two

Mr. Woodroffe. directions is probably due to the difference in the amount of working the plate gets in the two directions. If the steel could be rolled in each direction, the material would be better, first, as a result of the additional working, and second, because the slag would not be able to form in streaks, as it would probably be broken up by the cross-rolling. The only way that I can see, in which two complete workings of the material could be obtained, is to roll slabs from ingots, the slabs being then cut into lengths and rolled into plates in the opposite direction.

In conclusion, I would say that I appreciate the fact that such a change in the process would entail considerable expense upon the manufacturer, and we realize that as consumers we are not in a position to specify any process of manufacture; but we feel that firebox material in general would be vastly improved if the modifications we have suggested were adopted.

The Secretary.

THE SECRETARY.—The following communication bearing on the specifications for open-hearth boiler plate has just been received from Mr. Meier, chairman of Committee R on Uniform Specifications for Boilers:

NEW YORK, June 29, 1909.

THE AMERICAN SOCIETY FOR TESTING MATERIALS:

Your Committee R, in a report on uniform boiler specifications presented at the last annual meeting, recommended that the Society accept the joint specifications of the Association of American Steel Manufacturers and the American Boiler Manufacturers' Association, of December 22, 1905. This report was signed by six of the members of the Committee, but signature was refused by a minority of two. The majority represent builders and insurers of boilers, and testing engineers; the minority are steel plate manufacturers. The matter was referred to Committee A, which refused to change the specifications of the Society. As majority members of the Committee who signed this report, we deem it our duty to enter our respectful protest against this rejection of our recommendation.

The difference lies wholly in the chemical requirements. We deem it unsafe to allow more than 0.04 per cent. phosphorus or more than 0.03 per cent. sulphur in boiler steel. These maximum limits were first fixed by the American Boiler Manufacturers' Association in October, 1889, and were generally acquiesced in by the steel plate manufacturers, and there never has been any difficulty in obtaining plate which will fill these specifications. They correspond with the requirements of the United States Navy. During the twenty years since they were adopted much higher pressures and much greater capacity in evaporation have been

demand of boilers. It seems to us, therefore, unwise to reduce the requirements of the specifications for boiler plate. The Secretary.

The three members of our Committee not concurring in the above recommendations are Mr. F. B. Allen, Mr. C. L. Huston, and Mr. John McLeod.

Very respectfully submitted,

E. D. MEIER, *Chairman*.
R. C. CARPENTER,

H. J. HARTLEY,
H. V. WILLE.

The report of Committee R containing these recommendations, printed in the last volume of the Proceedings, was considered at a largely attended meeting of Committee A, at which were present consumers as well as manufacturers. Much time was devoted to the discussion of the subject, and the vote resulting in the rejection of these recommendations was practically unanimous. The reasons that prompted that action can be better presented by other members of Committee A, who are here; but I make that statement lest this communication might serve to convey an erroneous impression.

MR. G. E. THACKRAY.—The recommendation in its communication of a much lower phosphorus content than can practically be obtained, is apparently based largely upon hearsay evidence to this effect. In order that a statement of that kind should carry weight, it should be verified by facts, which have not been produced in sufficient or convincing manner. We all know that certain elements might have a deleterious effect when present in large quantities; but it does not necessarily follow that the difference between 0.04 and 0.06 phosphorus, or between 0.03 and 0.04 phosphorus, in a case of this kind, has any appreciable effect. In other words, it seems to me that before going to extremes in this matter, ample proof should be deduced in support of opinion. The case here is somewhat parallel to that of rails, in which extremely low phosphorus has been asked, and supplied at times, but without giving the extra good results that were expected. Mr. Thackray.

Attention was called at the time to the fact that in the attempt to furnish these very pure steels with low non-metallic contents, small quantities of the same might be produced in practice; but if any one particular person or purchaser should obtain these small quantities of especially pure steel, he would do so at the

Mr. Thackray. expense of the balance of the purchasing community. In other words, everybody cannot have the very best and purest.

Mr. Wickhorst. **MR. M. H. WICKHORST.**—I have given some little attention to the matter of firebox steel. You may remember that I read a paper here several years ago on the subject of firebox failures. My study of the matter makes me inclined not to be particular about getting the phosphorus and the sulphur to the lowest possible amounts obtainable; that is, it does not seem to be altogether necessary. What I mean is that the life of the firebox steel is more dependent on the conditions of service than on the quality of the material. For instance, you may find a sheet very wavy and corrugated. The presence of the corrugations is to me an evidence that the sheet has at some time been subjected to a red heat. I think that is of more importance in determining the life or service that the sheet is going to give than anything in connection with the quality of the material itself. We want a good quality of steel; but as compared with the abuse of the material, under conditions that no steel can be expected to resist, the matter of quality is relatively of little importance.

Mr. Thackray. **MR. THACKRAY.**—We all know the conditions of use of fireboxes and the extreme local temperatures to which parts of the same are subjected. May I suggest that the interior of the plates, especially, may be affected by absorption of sulphur from the coal or clinkers to an extent greater than the original sulphur content, and the fact that high sulphur is found in old firebox plates would not necessarily imply that the sulphur was all there in the first place. In other words, in use you may be putting in several times more sulphur than the manufacturer himself puts in, and, therefore, it is not altogether reasonable to ask for the very extreme low limits in the first instance.

Mr. Huston. **MR. C. L. HUSTON.**—I think I voice the sentiment of the steel manufacturers in general, although others can speak for themselves, in saying that they will all heartily cooperate in anything that is going to produce better results in service. The users of steel come back on us if they find the steel does not give good service. But this tendency of jumping on the sulphur and the phosphorus indiscriminately seems to me a little bit like moving in the line of least resistance. The poor manufacturer cannot help himself, for he has got to deliver goods, without any

increase in price or other consideration. There are many elements **Mr. Huston.** that undoubtedly enter into this question. We find that the physical difficulties are perhaps greater than the chemical difficulties in the production of steel. The tendency is to limit the specifications so that often the manufacturers have to reject, on fine technicalities just crossing the line of limitation, a lot of material which is as good as the plates that are regularly accepted. This makes the manufacturer feel that he is being subjected to an onerous restriction which causes him unnecessary trouble and increases the cost of manufacture, and ultimately the consumer has to bear the increased cost. I believe that boiler failures are very largely due to faulty mechanical or physical conditions which can be traced out with patience. The small benefit to be obtained by a little closer restriction of chemical limits will not correct the trouble but, on the other hand, it will very considerably increase the cost of manufacturing the material.

MR. ALBERT LADD COLBY.—I have been a member of Committee A ever since the Society began its work on the standardization of specifications. I am familiar with the requirements of all the specifications for firebox steel which have appeared during the past fifteen or twenty years, and have seen many analyses of American firebox steel during that period. **Mr. Colby.**

Between 1886 and 1892, when chemist of one of our large steel works, I made a special study of the methods for the determination of sulphur in iron and steel and was instrumental in bringing out evidence of what is now recognized as a fact among steel works' chemists, that the rapid volumetric methods in vogue in the 80's did not give the total sulphur contained in iron and steel.

The proposed modification by Committee R, to reduce the sulphur requirement from 0.04 to 0.03 per cent., is based on the requirement of an early specification of the American Boiler Manufacturers, which was arrived at by collecting a large number of analyses of commercial firebox steel then on the market. I am of the opinion that if the same samples of steel were analyzed for sulphur to-day, by our present more accurate volumetric or gravimetric methods, many of them would be found to contain 0.04 per cent. Hence it is not logical to make a reduction in the sulphur requirements of to-day on the basis of these old and inac-

Mr. Colby. curate determinations. Furthermore, much firebox steel containing about 0.04 per cent. of sulphur, is giving just as satisfactory service as steel with about 0.03 per cent. sulphur. For these reasons, I am not in favor of the modifications in our present sulphur requirements, proposed by certain members of Committee R.

Mr. Howe. MR. H. M. HOWE.—It does not seem wise to push these things too far. When you are getting sulphur down to 0.035 per cent., you are getting down pretty near the possible limit. You cannot make, as I understand, boiler plate steel of 0.02 sulphur; at least I think it cannot be done with American coal. I do not know that it is practicable to get it below 0.03 sulphur. When you reduce the limit to 0.035 you are requiring nearly as much as can possibly be done. If a manufacturer can possibly fulfill such extreme specifications, will he not do you more harm in some other way than he would in that way? When you force a man to extremes, is he going to have the control of his product in every other respect which he ought to have? It does not seem to me a wise thing, in order to gain so very little, to force a manufacturer to slight the work in some other way.

FURTHER INVESTIGATIONS OF BROKEN STEEL RAILS.

BY HENRY FAY AND R. W. G. WINT.

At the meeting of this Society in 1908, one of us presented a paper in which it was shown that steel rails, large caliber guns, and other material which contained manganese sulphide in elongated fibers or large masses, frequently broke and that the fracture invariably started in the sulphide areas before entering the metal itself. Experimental evidence was given showing the beginning of artificially produced cracks, which would always start in the sulphide areas, rather than in the steel itself, but which when once started always developed into the metal. Since then the investigation has been extended over a larger number of rails, which have fractured in various ways. At the present time the authors wish to emphasize the fact that it is not sulphide of manganese alone which is dangerous, but that other forms of slag are also sources of weakness. The term slag is very indefinite and usually includes everything to which we cannot apply a particular name. Unless otherwise stated, the term will be used in this paper to refer particularly to manganese silicate or to manganese sulphide, both of which have been described and their properties studied.

Beside these two forms of slag which are fairly well characterized, we may have to deal with other forms which have not been so well studied. In wrought iron, for instance, we have to contend with a silicate probably of indefinite or varying composition, depending upon the material from which the iron was made, and perhaps mixed with oxides or phosphates. We may also have to deal with oxides, but the evidence in this respect is as yet indefinite.

Sulphide of manganese and silicate of manganese have somewhat the same general appearance, but in most cases they can be distinguished by color or by the ease with which sulphide of manganese is attacked by acids. They frequently occur together and for this reason the term slag will be used instead of referring

to each separately. The effect upon the properties of the metal is, so far as studied, much the same. It is highly desirable to know the melting point of the silicate; with this data at hand more knowledge would be available in regard to its behavior during the rolling process.

Before discussing the experimental evidence, we wish to call attention to a paper, unfortunately overlooked a year ago, by Captain Howarth,* of the English Army. At the suggestion of the Ordnance Committee he studied the test pieces from gun tubes in which were shown greenish colored markings. These markings, identified as silicate of manganese by Mr. Stead, were often associated with sulphide of manganese. Captain Howarth states:

The markings are sometimes visible to the naked eye, but in most instances can only be detected with the aid of a microscope or hand glass. They vary in color, a sulphur-yellow streak with greenish tinge, about 0.03 in. broad, extending across the fracture, being the most common variety. Next in order of frequency come minute leaf-green markings; these are seldom massive, but occur as interrupted streaks in series. In some cases as much as 10 per cent. of the fracture is taken up by them.

In eighty-five forgings, green markings were noted in 8 per cent. of the muzzle and 11 per cent. of the breech tests. The muzzle end of the gun represents the upper part of the ingot, and the breech end the lower part. In all cases the author observed that the colored defects appeared most frequently at the bottom of the ingot, and more commonly in large ingots than in small ones.

Rosenhain, in a paper entitled "The Study of Breakages,"† gives the results of the microscopic examination of ruptured gun tubes and shows conclusively that the cracks extended through the medium of the slag spots. In this he not only confirms the work published in the Proceedings for 1908, but emphasizes the extreme importance of the absence of slag in high-class material.

It seems to the authors that renewed attention should be directed to the work of Thomas Andrews,‡ and especially to his paper entitled "Microscopic Internal Flaws Inducing Fracture in Steel." The paper is unfortunately written in a very diffuse

* *Journal Iron and Steel Institute*, 1905, No. II, p. 301.

† *Engineering*, September 11, 1908.

‡ *Engineering*, 1896.

manner, but gives the results, physical, chemical and microscopical, upon a large number of fractured rails, axles, tires, propeller shafts, and guns. It is important that in nearly all the material examined there was a considerable slag area in or near the fractured surface, and he says that the internal micro-flaws, which are almost invariably present in steel forgings, constitute a chief source of initial weakness in axles, rails, shafts, heavy guns, etc., and lead to their sudden fracture, or hasten the deterioration by fatigue.

In his work on steel rails, Mr. Job* makes a very significant statement; viz.,

Our experience has been that a rail with carbon as low as even 0.33 per cent. will not flow over under exceedingly heavy traffic, provided sound steel is present, with granular form, fine enough to render the metal tough and strong; and in every instance of flowing over or of breaking down of the side or corner of the head, we have found the presence of blowholes or other unsoundness near the surface or corners of the head, generally within $\frac{1}{8}$ or $\frac{1}{4}$ in. of the surface, whereas in the cases in which the rails have sustained long and heavy traffic, we have found comparative freedom from such defects.

If he had carefully examined microscopically the same specimens before etching, he would have been more strongly impressed with the importance of his observation, and also with the important rôle which slag plays. Indeed, if one consults the literature on the subject of broken steel of any character and examines the micro-photographs submitted as evidence, he will be much impressed with the large amount of slag in sight, no matter what the cause assigned for the breakage, whether it be coarse structure, segregation, or "mysterious."

It is not proposed in the present paper to discuss individual cases of broken rails, as it would lead to much repetition, but to treat as far as possible with definite types of fracture. In the paper of last year, evidence was produced to show that many crescent breaks were undoubtedly due to cracks beginning in and extending through elongated masses of manganese sulphide. The brittleness of manganese sulphide was also demonstrated. It was further shown that material which showed streaks, and manganese

* *Iron and Steel Magazine*, 10, 97.

sulphide is invariably associated with streaks, always broke along the lines of these streaks. Since then the extreme brittleness and low tenacity of this material has been shown in many cases and various ways. In addition to the tests which were made previously,

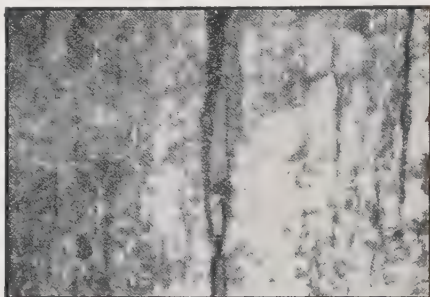


FIG. 1.

many new specimens containing sulphide in elongated areas were cut out of rails and subjected to strain. In each case cracks followed through and around these areas, as shown in Fig. 1.

Furthermore, it was noticed in many sections that the sulphide

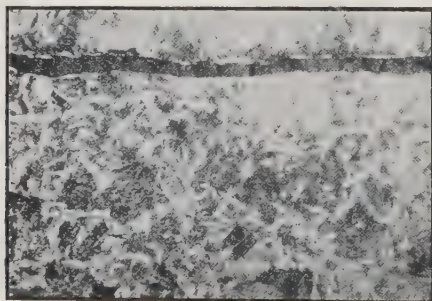


FIG. 2.

was broken at right angles to its direction of extension during the process of polishing, as shown in Fig. 2. This has proved to be a rather common phenomena and is the result of the various strains to which the sample is subjected in the course of preparation.

Another interesting development is presented in the case of a

high carbon steel which was known to have developed fire cracks. After annealing, a cross section of this bar was cut, polished, and etched, and at various points around the circumference decarbonized streaks were seen in which the sulphide was embedded in the characteristic way as shown in Fig. 3. It occurred to us

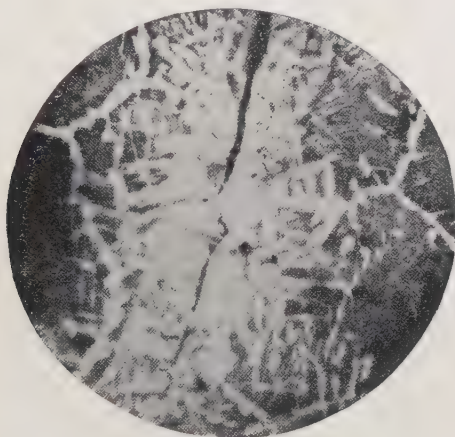


FIG. 3.

that perhaps the fire cracks might have originated in the sulphide areas. We accordingly prepared a section, carefully marked the areas by punch marks, and then gave it to a man experienced in hardening. The metal on quenching showed cracks running

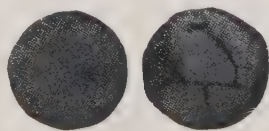


FIG. 4.

across the surface, each crack coinciding with the sulphide areas, as shown in Fig. 4. It must be borne in mind that this is only a single observation, and we do not wish to be put on record as stating that any fire cracks other than this particular one are due to this cause. It is significant, however, that the crack and sulphide coincide, which fact helps the accumulation of evidence

in favor of the dangerous character of included slag. A similar study of other fire-cracked material may yield interesting results.

At the meeting of this Society one year ago, Mr. Wickhorst presented a paper upon "Split Rail Heads," and through his courtesy we were able to study this same rail microscopically. The entire section was polished to a mirror surface, and two things became evident, viz., the surface was pitted extremely; and the area through which the pitting extended was concentric with the rail section, and the segregation within the area was large. The appearance of the split head and pitted surface is shown in Fig. 5. It will be noticed that the pitting is very extensive to the immediate right of the crack, and also somewhat further removed



FIG. 5.

to the left. Microscopic examination showed that the pitting was caused by the tearing out of the slag, which had been present in very large quantities. Much still remained and was of the characteristic dove-blue color of sulphide, although we prefer to refer to it in this case simply as slag, because of the different appearance in different parts of the rail. Mr. Wickhorst reports segregation of carbon, phosphorus and sulphur, and it is very significant to note that the sulphur in some places ran as high as 0.152 per cent., and that manganese was high where sulphur was high. This would indicate sulphide of manganese, but it is believed in this case that the sulphide was mixed with other forms of slag. Much of the slag was removed, and the general appearance of the polished surface before etching is shown in Fig. 6. This appearance is characteristic of the whole of the pitted area of the head. In the

smaller ends of the split portion some slag is seen in place, and its characteristic appearance is shown in Fig. 7. Whether or not sulphide of manganese or some other form of slag was the ultimate cause of this particular split head, we are not prepared to say, but we can strongly express the opinion that it was at least a contributing cause.

This opinion is strongly confirmed by our examination of many other split heads, which show in common the following facts:

1. Excessive slag (manganese sulphide, silicate, etc.).
2. Segregation of slag concentric with the section.

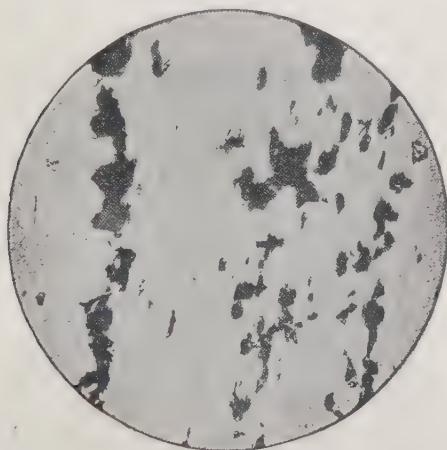


FIG. 6.

3. Remnants of slag in the large split portion of the head.
4. Slag in those areas where flow of metal has occurred or where microscopic cracks have developed.

It is quite impossible from the evidence which is obtainable to state with any definiteness the exact cause of fractures of this character. It is highly probable that imperfectly welded blow-holes or pipes are primarily the cause, but if so there is always associated with this a large amount of slag. It is conceivable that the presence of slag alone may account for fractures of this kind, although it will require much more experimental evidence to prove this conclusively.

Cracks invariably begin in and follow from one slag area to another. This may occur either on the surface or well within the metal. In a number of split head sections, and sections of rails in which there has been flow of metal, many small cracks have been observed, and almost invariably these cracks follow through slag or end in it. On the contrary, very rarely in the case of flow of metal is the metal free from slag. These observations fully coincide with those made by Mr. Job, previously quoted. Rails showing flow of metal are fairly common, and in nearly all cases where the metal flows over toward the side of the head, a crack



FIG. 7.

will be found in which is usually located some slag. The characteristic appearance of a rail showing flow is seen in Fig. 8. Inasmuch as any slag, irrespective of its nature, is more brittle than the steel itself, it will crumble before the steel does. When it crushes, it will fail to support the load above it, and the metal being ductile will flow. This process is similar to the tearing down of a building by beginning with knocking out the foundation stones. Slag located under the surface of the head of a rail will induce flow of metal; if present in excess it will cause ultimate break down.

Furthermore, cracks which have developed within the metal, due to shrinkage strains such as may be found in the interior of the

ingot, will follow through ferrite and from one slag area to another. Such areas as shown in Fig. 9 are very common. The segregation of the ferrite diminishes the strength of the metal at the point of segregation and if a crack once starts in either ferrite or slag, it will follow these areas. The illustration shown is taken from



FIG. 8.

a photograph of a rail in which there was considerable flow of metal on the running surface. The slag shown is manganese silicate. Flow of metal and microscopic cracks in such areas are very common and in practically every case examined the crack extends

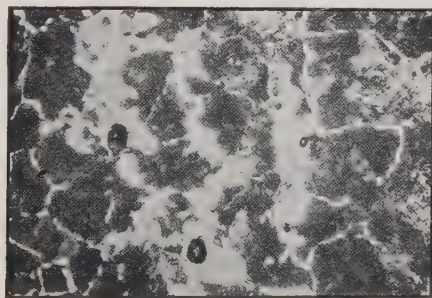


FIG. 9.

into a slag area. Whether or not such cracks are sometimes developed during the process of rolling and the slag injected at this time, is impossible to state, but it is believed that this sometimes happens, in which event the slag and cracks are invariably associated.

THE OCCURRENCE OF HARD SPOTS IN RAILS.

Hard spots in broken rails have been observed and are apparently due to one of three causes:

1. Imperfect mixing and solution of the ferro-manganese.
2. The hardening of the surface of the metal, due to slipping of the driving wheels.
3. Segregation in alloy steels.

The first cause is not a common one, but is occasionally met with. It may be recognized by the presence of undissolved ferro-manganese, which is easily identified by the free cementite. The hardness of the cementite being high, gives rise to a very hard, brittle spot which is usually detached during the process of machining the sample.

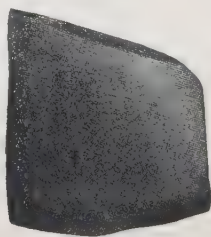


FIG. 10.

The second cause is also not a common one, but is more frequently observed. The hardened surface is the result of slipping of the locomotive driving wheel. Fig. 10 shows a section taken from the head of such a rail. The section was polished and etched with Kourbatoff's reagent. The micro-structure of the junction of the hard and soft areas is shown in Fig. 11. The mechanism of the fracture produced in such material is comparatively simple. The upper layer being extremely hard and brittle, soon develops a large number of fine hair cracks and some of these cracks ultimately develop in, and extend into and through the soft material. If the soft material happens to contain areas of sulphide or silicate of manganese, the propagation of the crack will be more rapid.

The third cause for hard spots is due to the imperfect melting of the alloy to be added. This is in some respects similar to the

first cause, but inasmuch as manganese is a regular constituent of rail steels, it was thought better to separate these two causes. We had occasion to examine several nickel steel rails which had broken in service, and which were so very hard that they could not

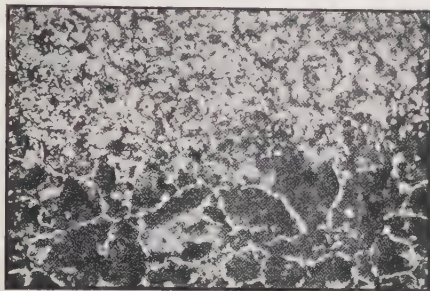


FIG. 11.

be machined. By sawing through the softer parts some sections were obtained by knocking off the harder parts with a hammer. In one of these rails were found streaks of very hard, medium

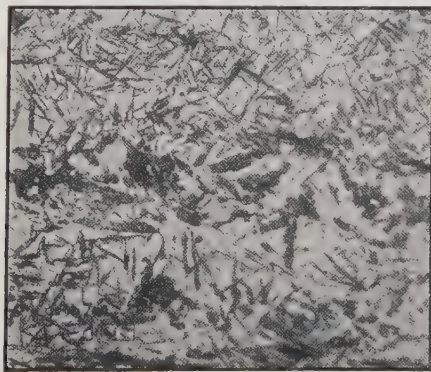


FIG. 12.

hard, and soft metal. These streaks were not only shown fairly well in the polished metal, but were brought out strongly on etching with 4 per cent. nitric acid in ethyl alcohol. The very hard streaks showed martensite with spots of troostite, as shown in

Fig. 12. In the medium hard streaks, the structure was distinctively sorbitic, as shown in Fig. 13, and also in Fig. 2, which was taken from the same rail. Fig. 14 shows the structure of the softer portion of the rail. It will thus be seen that this rail is a conglomerate mixture of martensite, troostite, sorbite, perlite, and ferrite, and long streaks of manganese sulphide. As each area was narrow and unevenly distributed, it was impossible to machine them out for analysis, but it is firmly believed that this lack of uniformity is due to segregation of the nickel.

Guillet has shown that, beginning with about 6 per cent. of nickel, martensite makes its appearance, and we undoubtedly have a similar case here. As the soft steel contains about 3.5 per

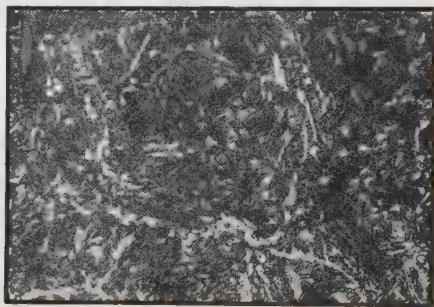


FIG. 13.

cent. nickel, the sorbitic portion, being a transition form between martensite and perlite, must contain less than 6 per cent. and more than 3.5 per cent. nickel. This assumption would seem to be confirmed by a similar experience with a nickel steel casting, which showed a very hard area. The surface showed the martensite structure after thorough annealing. Inasmuch as the percentage of nickel reported was about 3.5, it was considered desirable to determine the nickel immediately below the hard surface. Accordingly, drillings were obtained and the nickel was found to be 5.86 per cent.

As a result of our investigations on fractured material, rails, axles, etc., covering a period of several years, we are deeply impressed with the important rôle which slag plays in every case. All of the work which has been done since the meeting a year ago,

has served to emphasize and confirm the views then expressed. These views have received strong support in the work of Rosenhain, Captain Howarth, and Job. Furthermore, in the near future, additional evidence along this line will be published.

In regard to a remedy, we would like to emphasize those previously suggested, and we will adhere to this view until they have been given an impartial trial. We would again suggest the following as being the most important:

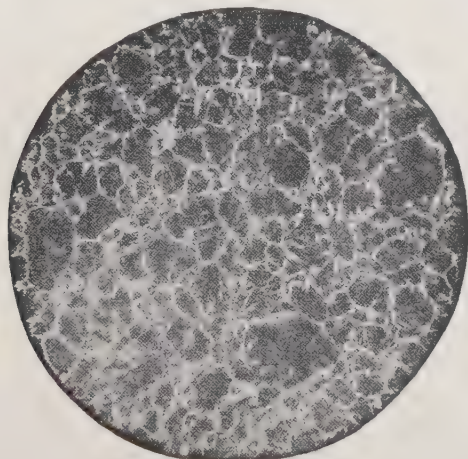


FIG. 14.

1. A specification asking for lower sulphur.
2. More time between the addition of ferro-manganese and pouring of the metal into the ingot.
3. Bottom pouring.

In addition, we believe that electric refining will remove many of the difficulties, but it must not be assumed that this is a general panacea. Bad steel can be produced just as easily in an electric furnace as by any other method, but under competent control the process is capable of producing valuable results.

[For Discussion of this paper, see page 106.]

INVESTIGATION OF DEFECTIVE OPEN-HEARTH STEEL RAILS.

BY ROBERT JOB.

During the past few years, the proportion of open-hearth rails rolled has increased rapidly, owing to the fact that by cutting down the phosphorus to a minimum a great increase in toughness results, rendering possible a much higher carbon content than is safe in a high phosphorus Bessemer rail, and hence a higher elastic limit, with increased hardness and capacity for wear. With good mill practice very favorable service results may be obtained, and we have known of instances in which such rails have averaged only one-third the wear found with the usual Bessemer rails when laid in track end to end with them, and under exactly the same conditions of service.

As has been pointed out repeatedly, the name "open-hearth" is not a talisman for the production of rails certain to give good service; it is well known that rails of this method of manufacture are subject to the same general defects which may be found in Bessemer rails, and hence require equal care during the process of manufacture. In the study of causes of failure of rails, striking instances occasionally occur which are of special interest in view of the results in service. An example of this type took place not long ago.

An open-hearth rail had broken in service into about forty pieces, derailing a train but fortunately causing no loss of life, and a critical examination was made to determine the exact cause of the failure. In the preliminary investigation we found that a blowhole began near the receiving end of the rail about $\frac{1}{2}$ in. below the top of the head, parallel with the surface of the latter, and extended clear to the running-off end of the rail. Within a short distance from the start the unwelded seam spread from one side of the head to the other, with oxidized surfaces. In the unbroken rail no defect could have been visible, and even after the fracture the only sign of defective condition upon the contour of the unbroken pieces was a faint line like a roll mark

along the side of the head, generally covered with mill scale. When the fracture came, evidently the $\frac{1}{2}$ -in. layer upon the top of the head cracked, throwing the end against the opposing wheels and thus causing the derailment, the remainder of the rail being ground into pieces by the force of the impact and the pounding of the wheels.

In order to study the condition of the steel, a transverse section was cut at a point about 3 ft. from the receiving end of the rail, and an analysis made of the borings, which were taken with a $\frac{5}{8}$ -in. drill about $\frac{1}{2}$ in. below the top of the web, showed the following composition:

Carbon.....	1.070	per cent.
Phosphorus	0.031	" "
Manganese	0.758	" "
Sulphur	0.025	" "

The heat average was about as follows:

Carbon.....	0.75	per cent.
Phosphorus	0.03	" "
Manganese	0.76	" "
Sulphur.....	0.05	" "

In order to note the extent of segregation in the section, borings were taken with the $\frac{5}{8}$ -in. drill about $\frac{1}{2}$ in. to the side of the center of head at a distance of $1\frac{1}{2}$ ins. from the location of the first borings, and the following composition was found:

Carbon	0.915	per cent.
Phosphorus.....	0.027	" "

From the above it is clear that radical segregation of the ingot existed, which accounted for a decided difference in the physical properties of the steel in closely adjacent places. The granular structure of the steel was about normal, showing that burning or overheating had not occurred.

As the next step in developing the physical character of the metal, we polished the surface of the section and found that the steel contained a large number of porous spongy spots, as shown in Fig. 1, taken in the natural size of the web. The condition of the head of the section is indicated in Fig. 2, with the blowhole extending across the head. Upon etching the steel slightly with

alcoholic iodine, we found additional indication of the unsound condition of the steel, as shown in Fig. 3, proving that the defects were not local but extended throughout the section. The fracture was unquestionably caused by the large blowhole across the head; but even if this had not been present, short life would have been certain to result owing to the general condition of unsoundness, for the fact that good service cannot be expected



FIG. 1.

from an unsound rail has been demonstrated so often that it has become an axiom.

In many cases of unsoundness the general location and character of the defect is indicated by the service which is given and the manner in which the rail begins to fail. When great porosity exists, or when much slag and other matter is present, as in Fig. 4, slivering generally follows after a short life, and the steel upon the outside edge of the head begins to flow, ultimately sloughs off, and is called "soft steel" by the trackmen, although

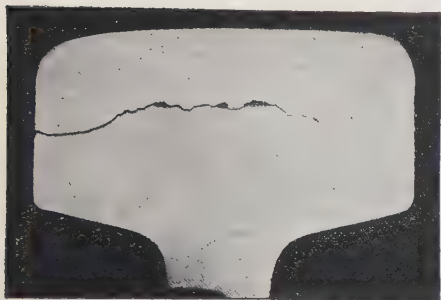


FIG. 2.

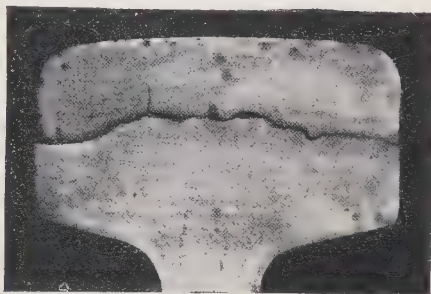


FIG. 3.

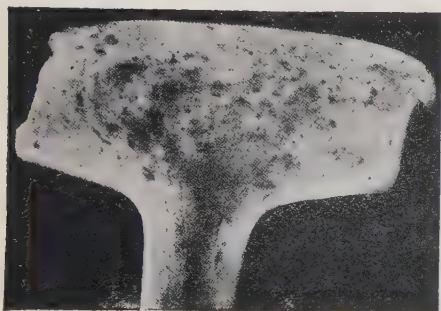


FIG. 4.



FIG. 5.



FIG. 6.



FIG. 7.

this action gives no indication of the carbon content; it is simply a consequence of unsoundness. Fig. 5 is a somewhat similar case of failure after a short service, although in this instance the rail fractured in track. In Fig. 6, fracture resulted from the porosity of the upper portion of the head. Indeed, we have found that the service suffers severely when unsoundness exists near the upper portion of the head, and fracture may occur, or the slivering and mashing down which has been shown above. When the same defects are somewhat below the surface, leaving a layer



FIG. 8.

of sound steel $\frac{1}{4}$ in. or so in width, good service often results until the sound metal has worn away.

The gradual course of failure of these unsound rails is interesting to follow. Fig. 7 shows a porous steel which has begun to sliver at the top and side of the head, showing also an unwelded seam down from the top of the head. In Fig. 8, the same general defective condition of the steel exists, although a plane of weakness has begun to develop in the short split in the left hand corner of the head. In Fig. 9, showing a similar rail, the crack has extended almost through the head, while in Fig. 10 we see the action completed, and the side of the head completely split off. In all of these instances the general condition of the



FIG. 9.

steel to the naked eye appears normal, but by developing the structure the defective character is readily seen.

In the investigation of broken rails, a characteristic form of the general type shown in Fig. 11 is occasionally found. A sharp, pronounced cut appears upon the top of the head of the



FIG. 10.



FIG. 11.

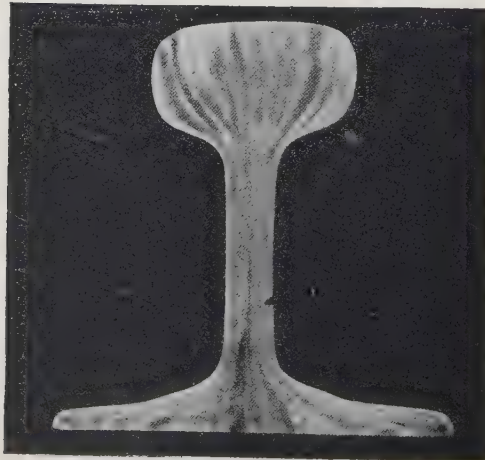


FIG. 12.

rail, with a straight, sheer cut extending into the steel $\frac{1}{8}$ in. or so, and then a smooth, split-off appearance extending well down toward the web. This condition has been caused by a blow from a sharp edge of a defective wheel, and we have known of instances in which scores of rails have been put out of commission, each with the distinctive mark, by a single defective wheel. The final fracture may not occur until the lapse of some little time after the damage has been done, but the plane is gradually extended from the original cut and on some sudden stress the rail is broken at the injured point.

As a contrast to present rail conditions, Fig. 12 indicates the method of manufacture of one of the earliest types of steel rails, called "German Steel." This metal, as is well known, was composed of alternate layers of iron and steel as shown in the light etching submitted, and is of interest as an illustration of one of the early steps taken years ago in the development of the steel rail.

[For Discussion of this paper, see page 106.]

DARK CARBON STREAKS IN SEGREGATED METAL IN SPLIT HEADS OF RAILS.

BY P. H. DUDLEY.

I have in former papers called attention to "split heads" in rails.* "Split head" has been distinctly recognized in the nomenclature of rail failures by the American Railway Engineering and Maintenance of Way Association, and is thus defined: "This term includes rails split through or near the center line of the head, or rails with pieces split off the sides of the head. When this term is used it should be further defined by stating whether it is or is not accompanied by a seam or hollow head." This was intended to be generic rather than specific with reference to types.

Fig. 1† shows a transverse section of the generic type of "split head" of rails. The spreading, wedge-shaped piece of metal above the opening in the head is indicated by the cracks in the bearing surface over the split. The metal of the wedge contains slag inclusions—manganese silicates as deoxidation products—from the chemical reactions of the recarburizer to purify and make the steel, while the deoxidation products did not have time to escape before the ingot was teemed into four length ingots for 100-lb. rails. The quality of the steel and the soundness of the ingots have been improved the past year or so by requiring more time for the deoxidation products to escape from the steel before teeming the ingots.

Fig. 2 shows in part by the dark discolorations an end progressive, detailed fracture of the web and base from the top of the web downward, after the head had split and separated at the junction of the web; also as a detailed fracture, the head separating from the web, reducing the rail from a single strong section into two weak sections, and failure is certain under a few thousand wheel loads, each extending the progressive fracture. The head was broken into several short pieces by the wheels of the train which

* Proceedings, Vol. V, p. 165; Vol. VII, p. 164.

† Acknowledgment is made to the *Railway and Engineering Review* for the cuts used in this paper.—ED.

was derailed. This is called a "piped" rail by the trackmen, but the fracture shows that the web was not split or did not contain a trace of blowholes or shrinkage cavities at this location. This is not always the case.

Fig. 3 includes the same piece of web, base, and head as Fig. 2, with the added portion of the broken piece from the head detached by the wheels. The half piece of the head projecting beyond the web contains a streak higher in carbon than the adjacent metal above or below it.

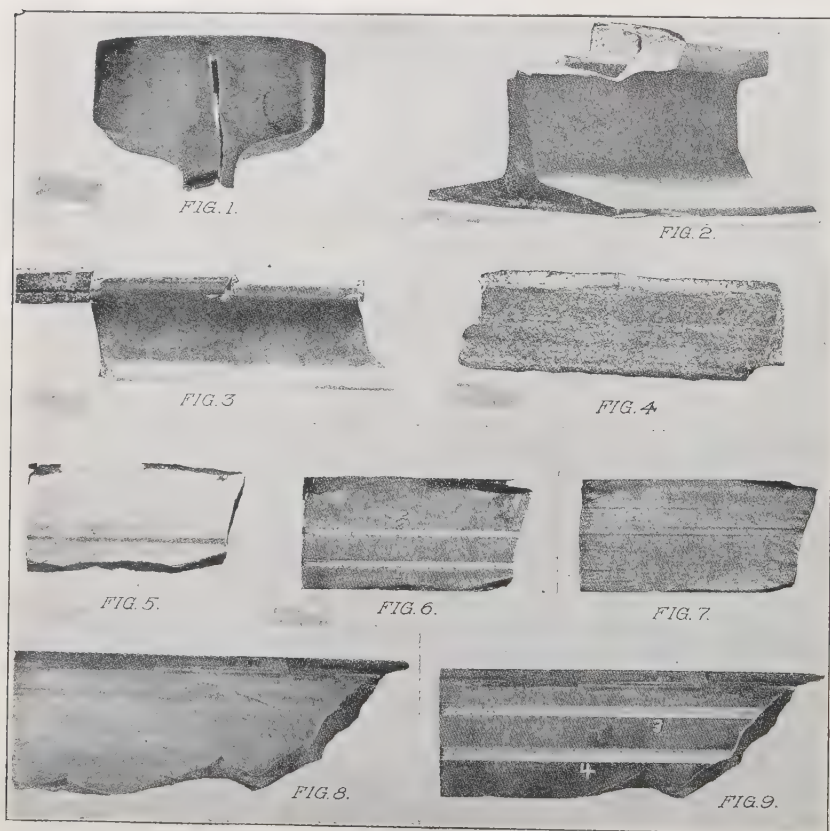
Fig. 4 is the inner face from the same "split head," and indicates a dark carbon streak near the middle of the head.

Fig. 5 is also the inner face from the same "split head," which was smoothed and etched to develop the dark carbon streak near the lower side of the head. This streak was practically in the same position as the one shown in Fig. 3, but all of the pieces of the head not being recovered, the fact could not be established whether it was or was not a continuation of the same streak. The fractured surface of Fig. 5, when received, was so recent that the metal was discolored only, and indicated that it had split in comparatively solid but segregated metal, confirming observations previously made and published. There were some indications of streaks on portions of the surface, proof that something had risen in the hot metal of the ingot before it had set, leaving the trail of its passage. This evidence is found frequently upon the fractured faces of the "split head," and is doubtless called a true seam by many observers. It seems to be the line of demarcation between the rising, interjected metal and that of the ingot, and easily becomes a cleavage plane of weakness. The steel did not set "dead," but the top of the ingot rose, forming a horn or horns with ejections of slag and impurities. An ingot with horns was cut and decided streaks found, while another was rolled into rails and sections, and cuts made of them contained many dark streaks.

I prepared the surface of Fig. 5 by hand, and saw at once that the streak was of harder metal than either side, and that the bulk of the so-called segregation had detached itself from the other half of the split head. The etching defined a well developed dark carbon streak (Fig. 5), although I had cut away over half of its thickness in surfacing the piece. Examination of the streak under the microscope indicated well defined longitudinal cracks, and

also that the metal was checked or shattered transversely in service. The sclerescope measured a hardness from 57 to 60 for the streaks, in comparison with 45 to 47 for the mass of the metal in the head.

Fig. 6 is the same piece as Fig. 5, and "1" in the illustration



shows where the dark carbon streak was planed out for chemical analysis, which by combustion was 0.78, while "2" shows where the steel was taken for the ordinary content of carbon, which was 0.61 by combustion and 0.49 by color. The streak was cut out $\frac{1}{8}$ in. wide and $\frac{1}{16}$ in. deep to obtain sufficient steel for a combustion test. These chips contained some material, approximately

one-third to one-half of the steel, which was not colored, the actual carbon being higher than the average reported. The highest content so far found in these dark carbon streaks in rails is 1.61 per cent. by combustion. The carbon in the strip marked "2" in Fig. 6 was 0.61 by combustion and 0.49 by color; the ladle tests of this lot of rails, manufactured in 1903, ran from 0.43 to 0.48 by color. The chemical analysis of the metal in the rail compared with the ladle tests, indicated segregation of the setting steel, which is further augmented by the interjections of the dark carbon streaks. The sharp demarcation between them and the adjacent metal surrounding them precludes the hypothesis that these are the nuclei of the so-called segregates which, owing to the richer carbon content, cooled last. Samples are being accumulated which indicate a dissemination of the higher carbon to the adjacent metal by the heat and work of fabrication. The rail did not fail until five and one-half years of service in the main line tracks, although many rails from the same lot failed as "split heads" after the second or third year of service. The rails of this brand were never lettered to mark their position in the ingot, but while uncertain, there are many indications that it was below the "A" rail of the top of the ingot. "Split heads" have been found in all rails of the ingot, though most frequently from the upper portion.

Fig. 7 is the same piece as Figs. 4, 5, and 6 after a reduction of $\frac{3}{8}$ in. in depth of the face, and shows slight impurity streaks, but not necessarily as high in carbon as the one cut out for analysis.

Fig. 8 shows a piece of the "split head" from the "B" rail of a 1903, 100-lb. "Dudley" section in a four-rail ingot. The rail was removed from the track as soon as indications of failure were noticed, for the purpose of securing as recent surfaces of the progressive, detailed fracture as possible. There were slight appearances of streaks on the fractured surfaces of the faces of the "split head," which, upon smoothing and polishing the specimen, developed near the upper surface of Fig. 8 as a faint, dark carbon streak. Immediately under the bearing surface, where the metal had spread under the passing wheel loads, two minute, dark streaks may be seen. These did not show a high content of carbon. The faint, broad, carbon streak gave the indication of increased hardness, measured by the sclerescope, of 57 to 60, as compared with 45 for the ordinary metal.

Fig. 9 is the same piece of steel, the figures "3" and "4" indicating where the portions were planed out for analyses. Cut "3" contained 0.72 per cent. of carbon by combustion and 0.61 by color. The metal below "4," a broad streak turned from the web by the rolls, was a mass of carbon in the steel. It showed 0.85 per cent. by combustion and 0.71 by color. The under surface of this piece was so high in carbon that it detached quickly from the head of the rail in the track—a usual type of fracture. It is not intended to convey the idea that all of the dark streaks found in the heads of these segregated rails will show high percentages of carbon, as in many instances its diffusion by the heat and work of manufacture is clearly evident. There are also oxides and other impurities which seem to be included in a central strip, the nature of which is under investigation. The fact that these dark carbon streaks are generally found in the head, shows that it is something which is injected irregularly into some, but not all, of the ingots of each heat of steel. They are not found in all, but only in occasional rails. We are, therefore, not dealing with a constant segregation, but rather with one of considerable irregularity.

Examination of the stools upon which the ingot molds set, shows that after teeming 100 to 120 heats they have lost oftentimes from 30 to 40 lbs. of metal. The molds are cut out by the stream of hot steel, and the cast iron enters the fluid steel which is being teemed. The cast iron is not cut out of the stool under each ingot of every heat. It seems to occur when the steel is high in temperature, and in falling from so great a height (6.5 to 8 ft.) it strikes the bottom of the stool with great severity, so that the ingots stick to the stool. The men teeming the ingots sometimes raise the stopper of the nozzle slightly to allow a little steel to fill the bottom of the mold before opening the nozzle full head. This checks the rapid cutting out of the stools, though after a number of heats have been teemed some of the cast iron of the stool becomes granulated and a portion is detached by the bottom of the ingot when stripped, if not by the falling stream. A new stool, from either of these causes, often loses 2 or 3 lbs. of metal on the first heat.

Examinations were made of ingots from which there were no traces of cast iron cut out by the falling stream in teeming the

ingots of that particular heat, and dark carbon streaks were not found in the rails from those ingots. Then a series of tests were made by casting small test ingots of 8 to 10-lb. weight, the same as those used for determining the chemical contents of the steel. The small quantity of steel poured from a hand ladle in the small ingots rarely cuts out any of the cast iron, and those ingots were free from dark carbon streaks. The experiment was then made of introducing an ounce or an ounce and a half of No. 1 iron drillings in the small test ingot. These ingots were then cut in half and polished, and dark streaks were found in the steel. These, upon being tested by the sclerescope, measured a greater hardness than the adjacent steel surrounding it by 8 to 10 points. Small test ingots have also been made in which about one or one and one-half ounces of cast iron from a broken mold were used. These pieces were put into the small test ingot after about one inch of metal had been poured into them. One ingot was cut and traces of the dark carbon streaks found in it. Another ingot with about the same quantity of cast iron from the mold was drawn out in a bar 1 in. square and about 30 ins. in length; this was then cut in half and polished, and the dark streaks were found in the interior of the bar. The cast iron caused the top of the test ingot to boil and form horns, as is often observed with the large ingots. The heat and work upon this small bar disseminated the carbon from the iron in streaks, so the total quantity at any one point was small, the carbon being well diffused each side of the small streak. The sclerescope showed a hardness of about 33 to 35 for the bar, and where the streaks of carbon were the heaviest the hardness was from 43 to 48.

The segregation of the ingots follows laws which have been observed to some extent, but it is considered remarkable that in rail ingots the manganese segregates to only a small extent. The equivalent increase is not found in the carbon streaks, for the possible reason that the cast iron contains only about 0.5 per cent. of manganese, and this would increase the manganese content only to a slight degree. I am now studying what I consider the normal segregation of an ingot which shows a fairly uniform segregation of all the elements. The small quantity of material in the carbon streaks is not usually sufficient for analyses of all the elements. There is an increase in the segregation of the phosphorus which

can be partially explained by the content in the cast iron, and also with the sulphur where it is injected into the steel. The accidental carbon streaks in rail steel render it difficult for the steel companies to prepare standards of uniform carbon content. The drillings taken from a bar in which these streaks are found will show decided irregularities under chemical analyses, even when drillings are taken from the same holes. Owing to the fineness of some of the material, it is difficult to make a uniform sample. With the facts known in reference to the effect of these carbon streaks in the steel, it will be better to take samples from ingots which have not taken up any iron from the stool, and these can be used to produce a more uniform standard. The carbon standards by color differ to a considerable extent at each mill and the values are not the same, which is partly due to the irregularities of the carbon streaks which occur in the steel.

The entire question of segregation will have to be carefully reconsidered, and the tests should be made upon steel which has not taken up any of the iron from the ingot molds or the stool.

The different results obtained by persons studying segregation can in a measure be explained by either the absence of the carbon streaks in the steel or their presence. It requires but a small amount of cast iron, containing 4 to 4.5 per cent. of carbon, to inject a large quantity in the interior of the steel. There are several instances in which the iron has not risen much above the crop of the bottom rail of the ingot. In other cases these streaks are found in the rails above the bottom, and sometimes they are only in the upper rails. The latter will occur when the steel is hot and there is ample time for the carbon to rise in the mold, and in ingots which boil, the carbon streaks and segregation are more decided than when the steel sets "dead."

The introduction of any deoxidizer which absorbs more of the oxygen of the steel and causes it to set more quietly, will reduce the natural segregation of the metal. I have made 17,000 tons of rails with ferro-titanium, and in many of them there is not the slightest trace of carbon streaks; but if there is an ingot of a heat which has cut out a portion of the stool, the carbon streaks appear.

Those rails which contained a percentage of the cast iron from the stool in the form of carbon streaks, are among those which

have broken most frequently in the track. Open-hearth steel from bottom poured ingots in which there is no cast iron cut out from the stools, has not shown carbon streaks.

In making these general experiments a great many samples have been examined, but not sufficient to cover the entire field of investigation at all of the different mills. It will be evident that the investigation of such a subject, which has heretofore not received any consideration, must be large and sufficiently comprehensive to cover all of the possibilities which may occur in the teeming of the ingots.

The present attitude of the steel makers with reference to the consumer is, that when facts are proved which have contributed to the unusual failures in rails, they are ready to take steps to reduce these possibilities in the future.

One eminent maker, after examining several of the dark carbon streaks in rails, said that there was little question in his mind but what a great many of the difficulties attributed to segregation are at least augmented by the cutting out of the cast iron from either the stool or the ingot mold.

GENERAL DISCUSSION ON STEEL RAILS.*

Mr. Kenney. MR. E. F. KENNEY.—In connection with Mr. Job's paper, I should like to ask as to the sulphur content of the second rail.

Mr. Job. MR. R. JOB.—The sulphur content was 0.025 per cent.

Mr. Kenney. MR. KENNEY.—That sulphur content is as low as one could possibly expect in the very best open-hearth steel, and should acquit sulphur in this particular instance. The stress laid on the sulphur content seems far fetched. We know that slag does damage, inasmuch as it destroys the continuity. That is all. Now it has been shown that the slag in question is composed mainly of the three elements, silicon, sulphur, and manganese. Why we should single out the sulphur and start a crusade on that, rather than the other two constituents of the objectionable slag, does not appear.

Mr. Job. MR. JOB.—In connection with the sulphur content it should be borne in mind, I think, that effects which were mentioned by Mr. Fay were caused by the presence of minute portions; and if the borings had been taken with a $\frac{3}{8}$ -in. drill, as was done in this case, the proportion of sulphur at that particular point might have been comparatively slight.

Mr. Howe. MR. H. M. HOWE.—In the molten metal you have oxides, you have silicates, you have sulphides, all mechanically suspended like sand, clay, organic matter, etc., in muddy water. You would naturally suppose that there would not be in any spot pure sulphide of manganese or silicate of iron alone, but that all these different substances would be mixed together like the fine constituents of mud. By boring down in one part of an ingot you would get

*This discussion covers the following papers:

Further Investigation of Broken Steel Rails.—Henry Fay and R. W. G. Wint.

An Investigation of a Defective Open-Hearth Steel Rail.—Robert Job.

The discussion includes no reference to the paper by Mr. P. H. Dudley on "Dark Carbon Streaks in Segregated Metal of 'Split Heads' of Rails," which in the absence of the author was read by title only.

more of one material than of another; but I should not suppose Mr. Howe. that you would find pure substances anywhere. I should like to ask Mr. Fay whether he has good reason to think that he does get a pure substance of one kind in one place, and another kind of pure substance in another place, instead of mixtures of all sorts in all the places, as I suppose would be the case?

On one of the rails which he showed us there were a great number of pits which I understood him to say were all filled originally with slag. If I recognize what he means by those pits, it implies too much slag, because they comprised about 25 or 30 per cent. of the volume of the rail, and if there were anything like even 10 per cent. of slag in the rail I should suppose that you would hear of it very soon when that rail went out to be delivered, because the specific gravity would be so far out. The running length and the weight of the shipment of rails would be so far from tallying that the difference would force itself on the attention of the officials of the road. It would not require a metallurgist to find it, because the rails would not weigh up.

I have observed in mirror polishing that pits are hard to remove. I have found that with patience I could get rid of what at first looked like genuine pits, but which were in fact nothing but the remains of old file marks. I would ask if it is certain that they are remnants of slag?

MR. HENRY FAY.—In reply to Mr. Howe, I would say that Mr. Fay. we find both pure substances, such as silicate and sulphide of manganese, and also mixtures of these two. In metal made from the top of the ingot we are more likely to find sulphide of manganese, while the silicate is most frequently found at the bottom. Pure sulphide of manganese readily disappears after treatment of the sample with free acid, and the silicate withstands the attack of dilute acids. By making observations before and after treatment, we can get some idea as to whether we are dealing with a pure substance or a mixture.

To my mind there can be no doubt of the pits being due to the presence of slag, as the results can be duplicated repeatedly by different observers and by various methods of polishing. If anyone doubts this fact he can readily convince himself by mirror polishing a sample of wrought iron, in which he will be able to develop the characteristic slag lines.

Mr. Thackray.

MR. G. E. THACKRAY.—With all due respect to the laudable desire of investigators on these lines to know the true inwardness of things, it strikes me, that in carrying these microscopic investigations to the extreme point of high magnifications, they are likely to distort their own imaginations to a somewhat similar extent; in other words, small things look large, and it is a question in my mind how much influence these little flaws have upon the real life or wear of a piece of steel. I must confess to some ignorance in matters of this kind, but it strikes me that there is no substance which, when subjected to high magnifications, will not show lack of homogeneity, whether it be the product of nature, or whether it be the product of man.

Mr. Fay.

MR. FAY.—In regard to the examination of diseased material, I believe there has been much bad material examined, but at the same time good material has been examined also. We know the landmarks of good material and we are now attempting to establish similar points for bad material. I think it is well worth pointing out that the steel manufacturer has examined neither good nor bad material. If the steel manufacturer himself will help us along these lines, I think it will be much better than to simply play the part of critic. Cooperation in this work is what we want.

Mr. Howe.

MR. HOWE.—I think the practical steel manufacturers may have made more examinations than Mr. Fay is aware of. I think there is a great deal of truth in what Mr. Thackray says, but I would put it the other way. I think we who examine with the microscope ought to consider it very important to compare the abnormal with the normal; but I think above all things it is very important to be extremely cautious in interpreting the results of the microscope. It is very easy to look through a microscope, it is very easy to polish and etch sections, but it is extremely difficult to interpret what you see, because in very large part you see what you look for. The microscope is, in large part, an instrument for obtaining any desired result.

The President.

THE PRESIDENT.—I do not think I can quite agree with the statements made by either side. I think there is an unsolved problem here in this matter that really needs very careful investigation. I will take my illustration from the rail. Let us assume that a rail which contains a lot of manganese sulphide or man-

ganese silicate goes into the tracks. There is danger that this rail The President. under certain conditions, as has been claimed and as I believe, might break due to the presence of those impurities. But to make a better rail means greater expense. I believe it is in the power of the steel rail-maker to-day to make better steel than he is making. I believe that to allow the steel to stand a little longer in the ladle after the final additions are made, will relieve a good deal of the difficulty that Mr. Fay has discovered as the result of his microscopic investigations. It looks also as though the electric furnace might accomplish the same result in a different way. But here is the unsolved problem. Is it worth while to make better steel? I answer as follows: If it costs more to make better rails than it does to give poorer rails such support in the track that they will not break under the conditions of service, it is not worth while to make better rails. On the other hand, if a better rail will diminish the cost of maintaining the track, more than the increase in the cost of the rail, better rails are certainly an absolute desideratum. Unfortunately we do not yet know where the true economy lies. It is hoped that the data which is now being obtained from rails in service, will enable this problem to be solved.

REPORT OF COMMITTEE B ON STANDARD SPECIFICATIONS FOR CAST IRON AND FINISHED CASTINGS.

Your Committee B would submit the following as their report of the work done during the past year:

The Committee on Pig Iron reports that, following the specifications presented at the last annual meeting and the resolutions that were then passed, they have repeatedly discussed the subject of uniform specifications with the American Foundrymen's Association, and have arranged for uniform specifications (and variations therefrom) for the elements that are usually associated with pig iron. The Committee would ask for their acceptance by the Convention, and their prompt submission by letter ballot to the members of the Society, so that they can be presented at the International Congress at Copenhagen next September as being finally approved.

The specifications, as adopted by the American Foundrymen's Association, include clauses for the purpose of adjusting disputes between buyer and seller. This Committee recommends their use for such purposes.

Nothing came before the remaining sub-committees of Committee B that has called for their discussion or action during the past year. This applies to the following: Committees on Cast Iron Pipe, on Cylinders, on Car Wheels, on Malleable Cast Iron, on General Castings, on Testing Cast Iron, on Influence of the Addition of Special Metals to Cast Iron, and on Micro-Structure of Cast Iron.

Respectfully submitted on behalf of the Committee,

WALTER WOOD,
Chairman.

RICHARD MOLDENKE,
Secretary.

NOTE.—The Specifications for Foundry Pig Iron were adopted by letter ballot of the Society on August 16, 1909, and follow this report.—ED.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR FOUNDRY PIG IRON.*

ADOPTED AUGUST 16, 1909.

PERCENTAGES AND VARIATIONS.

In order that there may be uniformity in grading, the following percentages and variations shall be used.†

<i>Silicon.</i>		<i>Sulphur.</i>			
Per cent.	Code.	Per cent.	Code.		
1.00	La	0.04	Sa		
1.50	Le	0.05	Se		
2.00	Li	0.06	Si		
2.50	Lo	0.07	So		
3.00	Lu	0.08	Su		
3.50	Ly	0.09	Sy		
		0.10	Sh		
(0.25 allowed either way.)		(Maximum.)			
<i>Total Carbon</i>		<i>Manganese.</i>		<i>Phosphorus.</i>	
Per cent.	Code.	Per cent.	Code.	Per cent.	Code.
3.00	Ca	0.20	Ma	0.20	Pa
3.20	Ce	0.40	Me	0.40	Pe
3.40	Ci	0.60	Mi	0.60	Pi
3.60	Co	0.80	Mo	0.80	Po
3.80	Cu	1.00	Mu	1.00	Pu
		1.25	My	1.25	Py
		1.50	Mh	1.50	Ph
(Minimum.)		(0.20 allowed either way.)		(0.15 allowed either way.)	

* It is recommended that foundry pig iron be bought by analysis, and that when so bought these Standard Specifications be used.

† These specifications do not advise that all five elements be specified in all contracts for pig iron, but do recommend that when these elements are specified, the given percentages shall be used.

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Illustration of the use of above coding: The word Li-se-ca-mo-pi indicates

Sil.	Sul.	Carb.	Mang.	Phos.
2.00	0.05	3.00	0.80	0.60

with variations as allowed.

Percentages of any element specified half way between the above shall be designated by the addition of the letter X to the next lower symbol.

Example.—PeX indicates Phosphorus 0.50, with “allowed” variations (0.15) up and down.

In the case of phosphorus and manganese, the percentages may be used as maximum or minimum figures, but unless so specified they will be considered to include the variations above given.

SAMPLING AND ANALYSIS.

Each car load, or its equivalent, shall be considered as a unit in sampling.

One sample shall be taken to every four tons in the car, and shall be so chosen from different parts of the car as to represent as nearly as possible the average quality of the iron.

Drillings shall be taken so as to fairly represent the composition of the pig as cast.

An equal weight of the drillings from each pig shall be thoroughly mixed to make up the sample for analysis.

In case of dispute, the sampling and analysis shall be made by an independent chemist, mutually agreed upon, if practicable, at the time the contract is made.

It is recommended that the standard methods of the American Foundrymen's Association be used for analysis. Gravimetric methods shall be used for the analysis of sulphur, unless otherwise specified in the contract.

The cost of re-sampling and re-analysis shall be borne by the party in error.

BASE OR QUOTING PRICE.

For market quotations, an iron of 2.00 per cent. in silicon (with variations of 0.25 either way) and 0.05 per cent. in sulphur (maximum) shall be taken as the base.

STANDARD SPECIFICATIONS FOR FOUNDRY PIG IRON. 113

THE AMERICAN FOUNDRYMEN'S ASSOCIATION SUGGESTS THE FOLLOWING CLAUSES FOR THE PURPOSE OF ADJUSTING DISPUTES BETWEEN BUYER AND SELLER.

Base Table.—The following table may be filled out, and may become a part of the contract. "B", or Base, represents the price agreed upon for a pig iron running 2.00 per cent. in silicon (with allowed variation of 0.25 either way) and under 0.05 per cent. in sulphur; "C" is a constant differential to be determined at the time the contract is made.

This table is for settling any differences which may arise in filling a contract, as explained under penalties and allowances, and may be used to regulate the price of a grade of pig iron which the purchaser desires, and the seller agrees, to substitute for the one originally specified.

Silicon percentages allow 0.25 variation either way. Sulphur percentages are maximum.

<i>Sulphur,</i> <i>per cent.</i>	<i>Silicon, per cent.</i>									
	3.25	3.00	2.75	2.50	2.25	2.00	1.75	1.50	1.25	1.00
0.04..B+6C	B+5C	B+4C	B+3C	B+2C	B+1C	B	B-1C	B-2C	B-3C	B-4C
0.05..B+5C	B+4C	B+3C	B+2C	B+1C	B	B-1C	B-2C	B-3C	B-4C	B-5C
0.06..B+4C	B+3C	B+2C	B+1C	B	B-1C	B-2C	B-3C	B-4C	B-5C	B-6C
0.07..B+3C	B+2C	B+1C	B	B-1C	B-2C	B-3C	B-4C	B-5C	B-6C	B-7C
0.08..B+2C	B+1C	B	B-1C	B-2C	B-3C	B-4C	B-5C	B-6C	B-7C	B-8C
0.09..B+1C	B	B-1C	B-2C	B-3C	B-4C	B-5C	B-6C	B-7C	B-8C	B-9C
0.10..B	B-1C	B-2C	B-3C	B-4C	B-5C	B-6C	B-7C	B-8C	B-9C	

Penalties.—In case the iron, when delivered, does not conform to the specifications, the buyer shall have the option of either refusing the iron, or accepting it on the basis shown in the above table, which must be filled out at the time the contract is made.

Allowances.—In case the furnace cannot, for any good reason, deliver the iron as specified at the time delivery is due, the purchaser may at his option accept any other analysis which the furnace can deliver, the price to be determined by the base table above, which must be filled out at the time the contract is made.

REPORT OF COMMITTEE C ON STANDARD SPECIFICATIONS FOR CEMENT.

Your Committee on Standard Specifications for Cement desires to recommend the following changes in the Standard Specifications for Cement:

1. To amend the requirements for specific gravity of Portland Cement to read as follows: "The specific gravity of cement shall not be less than 3.10. Should the test of cement as received fall below this requirement, a second test may be made upon a sample ignited at a low red heat. The loss in weight of the ignited cement shall not exceed 4 per cent."

2. To amend the requirements for tensile strength, for both Natural and Portland Cement, as follows:

NATURAL CEMENT.

The minimum requirements for tensile strength for briquettes one square inch in cross section shall be as follows, and the cement shall show no retrogression in strength within the periods specified:

<i>Age.</i>	<i>Neat Cement.</i>	<i>Strength.</i>
24 hours in moist air		75 lbs.
7 days (1 day in moist air, 6 days in water)		150 "
28 days (1 " " " 27 " ")		250 "

One Part Cement, Three Parts Standard Ottawa Sand.

7 days (1 day in moist air, 6 days in water)	50 lbs.
28 days (1 " " " 27 " ")	125 "

PORTLAND CEMENT.

The minimum requirements for tensile strength for briquettes one square inch in cross section shall be as follows, and the cement shall show no retrogression in strength within the periods specified:

<i>Age.</i>	<i>Neat Cement.</i>	<i>Strength.</i>
24 hours in moist air		175 lbs.
7 days (1 day in moist air, 6 days in water)		500 "
28 days (1 " " " 27 " ")		600 "

One Part Cement, Three Parts Standard Ottawa Sand.

7 days (1 day in moist air, 6 days in water).....200 lbs.
 28 days (1 " " " 27 " ").....275 "

Respectfully submitted on behalf of the Committee,

GEORGE F. SWAIN,
Chairman.

RICHARD L. HUMPHREY,
Secretary.

NOTE.—The above proposed amendments to the Standard Specifications for Cement were adopted by letter ballot of the Society on August 16, 1909. The specifications as amended, as well as the methods of testing proposed by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers, in their amended form, follow this report.—ED.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR CEMENT.

ADOPTED AUGUST 16, 1909.

GENERAL OBSERVATIONS.

1. These remarks have been prepared with a view of pointing out the pertinent features of the various requirements and the precautions to be observed in the interpretation of the results of the tests.

2. The Committee would suggest that the acceptance or rejection under these specifications be based on tests made by an experienced person having the proper means for making the tests.

SPECIFIC GRAVITY.

3. Specific gravity is useful in detecting adulteration. The results of tests of specific gravity are not necessarily conclusive as an indication of the quality of a cement, but when in combination with the results of other tests may afford valuable indications.

FINENESS.

4. The sieves should be kept thoroughly dry.

TIME OF SETTING.

5. Great care should be exercised to maintain the test pieces under as uniform conditions as possible. A sudden change or wide range of temperature in the room in which the tests are made, a very dry or humid atmosphere, and other irregularities vitally affect the rate of setting.

CONSTANCY OF VOLUME.

6. The tests for constancy of volume are divided into two classes, the first normal, the second accelerated. The latter should be regarded as a precautionary test only, and not infallible. So many conditions enter into the making and interpreting of it that it should be used with extreme care.

7. In making the pats the greatest care should be exercised to avoid initial strains due to molding or to too rapid drying-out during the first twenty-four hours. The pats should be preserved under the most uniform conditions possible, and rapid changes of temperature should be avoided.

8. The failure to meet the requirements of the accelerated tests need not be sufficient cause for rejection. The cement may, however, be held for twenty-eight days, and a retest made at the end of that period, using a new sample. Failure to meet the requirements at this time should be considered sufficient cause for rejection, although in the present state of our knowledge it cannot be said that such failure necessarily indicates unsoundness, nor can the cement be considered entirely satisfactory simply because it passes the tests.

SPECIFICATIONS.

GENERAL CONDITIONS.

1. All cement shall be inspected.
2. Cement may be inspected either at the place of manufacture or on the work.
3. In order to allow ample time for inspecting and testing, the cement should be stored in a suitable weather-tight building having the floor properly blocked or raised from the ground.
4. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment.
5. Every facility shall be provided by the Contractor and a period of at least twelve days allowed for the inspection and necessary tests.
6. Cement shall be delivered in suitable packages with the brand and name of manufacturer plainly marked thereon.
7. A bag of cement shall contain 94 pounds of cement net. Each barrel of Portland cement shall contain 4 bags, and each barrel of natural cement shall contain 3 bags of the above net weight.

8. Cement failing to meet the seven-day requirements may be held awaiting the results of the twenty-eight-day tests before rejection.

9. All tests shall be made in accordance with the methods proposed by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers, presented to the Society January 21, 1903, and amended January 20, 1904, and January 15, 1908, with all subsequent amendments thereto. (See addendum to these specifications.)

10. The acceptance or rejection shall be based on the following requirements:

NATURAL CEMENT.

11. *Definition.* This term shall be applied to the finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to drive off the carbonic acid gas.

FINENESS.

12. It shall leave by weight a residue of not more than 10 per cent. on the No. 100, and 30 per cent. on the No. 200 sieve.

TIME OF SETTING.

13. It shall not develop initial set in less than ten minutes; and shall not develop hard set in less than thirty minutes, or in more than three hours.

TENSILE STRENGTH.

14. The minimum requirements for tensile strength for briquettes one square inch in cross section shall be as follows, and the cement shall show no retrogression in strength within the periods specified:

<i>Age.</i>	<i>Neat Cement.</i>	<i>Strength.</i>
24 hours in moist air.....		75 lbs.
7 days (1 day in moist air, 6 days in water)...		150 "
28 days (1 " " " 27 " ")...		250 "
<i>One Part Cement, Three Parts Standard Ottawa Sand.</i>		
7 days (1 day in moist air, 6 days in water)...		50 lbs.
28 days (1 " " " 27 " ")...		125 "

CONSTANCY OF VOLUME.

15. Pats of neat cement about three inches in diameter, one-half inch thick at center, tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(a) A pat is then kept in air at normal temperature.

(b) Another is kept in water maintained as near 70° F. as practicable.

16. These pats are observed at intervals for at least 28 days, and, to satisfactorily pass the tests, shall remain firm and hard and show no signs of distortion, checking, cracking, or disintegrating.

PORTLAND CEMENT.

17. *Definition.* This term is applied to the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than 3 per cent. has been made subsequent to calcination.

SPECIFIC GRAVITY.

18. The specific gravity of cement shall not be less than 3.10. Should the test of cement as received fall below this requirement, a second test may be made upon a sample ignited at a low red heat. The loss in weight of the ignited cement shall not exceed 4 per cent.

FINENESS.

19. It shall leave by weight a residue of not more than 8 per cent. on the No. 100, and not more than 25 per cent. on the No. 200 sieve.

TIME OF SETTING.

20. It shall not develop initial set in less than thirty minutes; and must develop hard set in not less than one hour, nor more than ten hours.

TENSILE STRENGTH.

21. The minimum requirements for tensile strength for briquettes one square inch in cross section shall be as follows, and

the cement shall show no retrogression in strength within the periods specified:

<i>Age.</i>	<i>Neat Cement.</i>	<i>Strength.</i>
24 hours in moist air.....		175 lbs.
7 days (1 day in moist air, 6 days in water)...		500 "
28 days (1 " " " 27 " ")...		600 "

One Part Cement, Three Parts Standard Ottawa Sand.

7 days (1 day in moist air, 6 days in water)...	200 lbs.
28 days (1 " " " 27 " ")...	275 "

CONSTANCY OF VOLUME.

22. Pats of neat cement about three inches in diameter, one-half inch thick at the center, and tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(a) A pat is then kept in air at normal temperature and observed at intervals for at least 28 days.

(b) Another pat is kept in water maintained as near 70° F. as practicable, and observed at intervals for at least 28 days.

(c) A third pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel for five hours.

23. These pats, to satisfactorily pass the requirements, shall remain firm and hard, and show no signs of distortion, checking, cracking, or disintegrating.

SULPHURIC ACID AND MAGNESIA.

24. The cement shall not contain more than 1.75 per cent. of anhydrous sulphuric acid (SO_3), nor more than 4 per cent. of magnesia (MgO).

ADDENDUM.

ABSTRACT OF METHODS RECOMMENDED BY THE SPECIAL
COMMITTEE ON UNIFORM TESTS OF CEMENT OF THE
AMERICAN SOCIETY OF CIVIL ENGINEERS.

SAMPLING.

1.—*Selection of Sample.*—The sample shall be a fair average of the contents of the package; it is recommended that, where conditions permit, one barrel in every ten be sampled.

2.—Samples should be passed through a sieve having twenty meshes per linear inch, in order to break up lumps and remove foreign material; this is also a very effective method for mixing them together in order to obtain an average. For determining the characteristics of a shipment of cement, the individual samples may be mixed and the average tested; where time will permit, however, it is recommended that they be tested separately.

3.—*Method of Sampling.*—Cement in barrels should be sampled through a hole made in the center of one of the staves, midway between the heads, or in the head, by means of an auger or a sampling iron similar to that used by sugar inspectors. If in bags, it should be taken from surface to center.

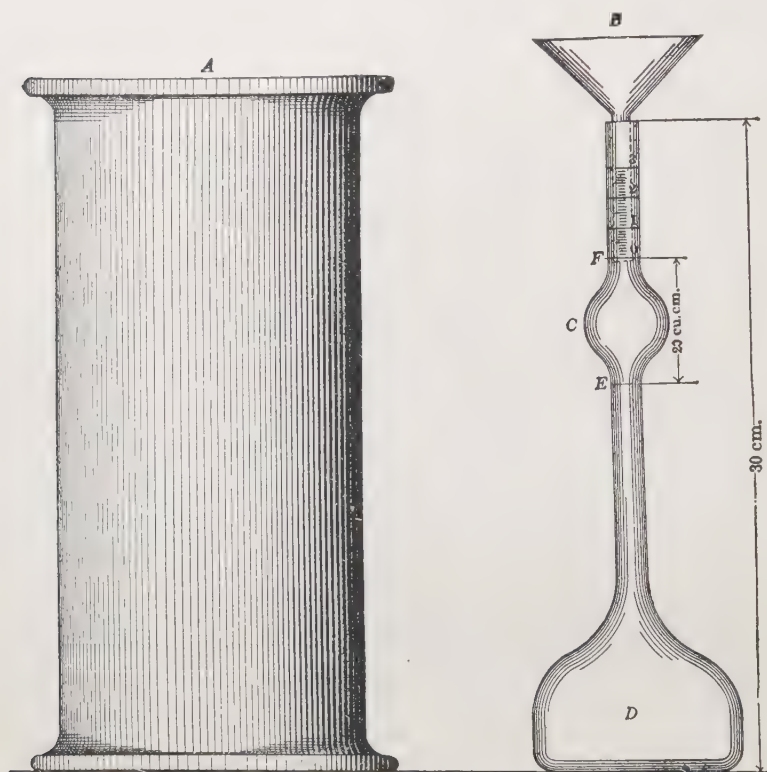
CHEMICAL ANALYSIS.

4.—*Method*—As a method to be followed for the analysis of cement, that proposed by the Committee on Uniformity in the Analysis of Materials for the Portland Cement Industry, of the New York Section of the Society for Chemical Industry, and published in the *Journal* of the Society for January 15, 1902, is recommended.

SPECIFIC GRAVITY.

5.—*Apparatus and Method.*—The determination of specific gravity is most conveniently made with Le Chatelier's apparatus. This consists of a flask (*D*), Fig. 1, of 120 cu. cm. (7.32 cu. ins.) capacity, the neck of which is about 20 cm. (7.87 ins.) long; in the middle of this neck is a bulb (*C*), above and below which are two marks (*F*) and (*E*); the volume between these marks is 20 cu. cm. (1.22 cu. ins.). The neck has a diameter of about 9 mm. (0.35 in.), and is graduated into tenths of cubic centimeters above the mark (*F*).

6.—Benzine (62° Baumé naphtha), or kerosene free from water should be used in making the determination.



LE CHATELIER'S SPECIFIC GRAVITY APPARATUS

Fig. 1.

7.—The specific gravity can be determined in two ways.

(1) The flask is filled with either of these liquids to the lower mark (E), and 64 gr. (2.25 oz.) of powder, cooled to the temperature of the liquid, is gradually introduced through the funnel (B) [the stem of which extends into the flask to the top of the bulb (C)], until the upper mark (F) is reached. The difference in weight between the cement remaining and the original quantity (64 gr.) is the weight which has displaced 20 cu. cm.

8.—(2) The whole quantity of the powder is introduced, and the level of the liquid rises to some division of the graduated neck. This reading plus 20 cu. cm. is the volume displaced by 64 gr. of the powder.

9.—The specific gravity is then obtained from the formula:

$$\text{Specific Gravity} = \frac{\text{Weight of Cement, in grams.}}{\text{Displaced Volume, in cubic centimeters.}}$$

10.—The flask, during the operation, is kept immersed in water in a jar (A), in order to avoid variations in the temperature of the liquid. The results should agree within 0.01. The determination of specific gravity should be made on the cement as received; and, should it fall below 3.10, a second determination should be made on the sample ignited at a low red heat.

11.—A convenient method for cleaning the apparatus is as follows: The flask is inverted over a large vessel, preferably a glass jar, and shaken vertically until the liquid starts to flow freely; it is then held still in a vertical position until empty; the remaining traces of cement can be removed in a similar manner by pouring into the flask a small quantity of clean liquid and repeating the operation.

FINENESS.

12.—*Apparatus.*—The sieves should be circular, about 20 cm. (7.87 ins.) in diameter, 6 cm. (2.36 ins.) high, and provided with a pan, 5 cm. (1.97 ins.) deep, and a cover.

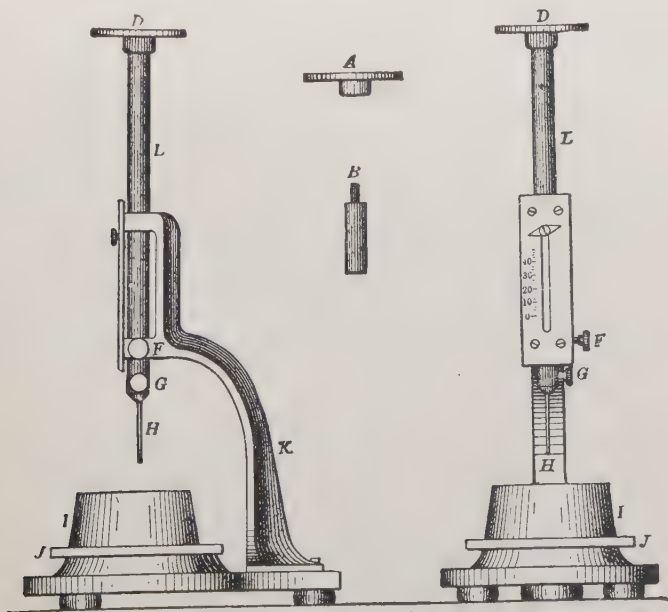
13.—The wire cloth should be of brass wire having the following diameters:

No. 100, 0.0045 in.; No. 200, 0.0024 in.

14.—This cloth should be mounted on the frames without distortion; the mesh should be regular in spacing and be within the following limits:

No. 100, 96 to 100 meshes to the linear inch.

No. 200, 188 to 200 " " " "



VICAT NEEDLE.

FIG. 2.

15.—Fifty grams (1.76 oz.) or 100 gr. (3.25 oz.) should be used for the test, and dried at a temperature of 100° C. (212° F.) prior to sieving.

16.—*Method*.—The thoroughly dried and coarsely screened sample is weighed and placed on the No. 200 sieve, which, with pan and cover attached, is held in one hand in a slightly inclined position, and moved forward and backward, at the same time striking the side gently with the palm of the other hand, at the rate of about 200 strokes per minute. The operation is continued until not more than one-tenth of 1 per cent passes through after one minute of continuous sieving. The residue is weighed, then placed on the No. 100 sieve and the operation repeated. The work may be expedited by placing in the sieve a small quantity of steel shot. The results should be reported to the nearest tenth of 1 per cent.

NORMAL CONSISTENCY.

17.—*Method*.—This can best be determined by means of *Vicat Needle Apparatus*, which consists of a frame (*K*), Fig. 2, bearing a movable rod (*L*), with the cap (*A*) at one end, and at the other the cylinder (*B*), 1 cm. (0.39 in.) in diameter, the cap, rod and cylinder weighing 300 gr. (10.58 oz.). The rod, which can be held in any desired position by a screw (*F*), carries an indicator, which moves over a scale (graduated to centimeters) attached to the frame (*K*). The paste is held by a conical, hard-rubber ring (*I*), 7 cm. (2.76 ins.) in diameter at the base, 4 cm. (1.57 ins.) high, resting on a glass plate (*J*), about 10 cm. (3.94 ins.) square.

18.—In making the determination, the same quantity of cement as will be subsequently used for each batch in making the briquettes (but not less than 500 grams) is kneaded into a paste, as described in paragraph 39, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained 6 ins. apart; the ball is then pressed into the rubber ring, through the larger opening, smoothed off and placed (on its large end) on a glass plate and the smaller end smoothed off with a trowel; the paste, confined in the ring, resting on the plate, is placed under the rod bearing the cylinder, which is brought in contact with the surface and quickly released.

19.—The paste is of normal consistency when the cylinder penetrates to a point in the mass 10 mm. (0.39 in.) below the top of the ring. Great care must be taken to fill the ring exactly to the top.

20.—The trial pastes are made with varying percentages of water until the correct consistency is obtained.

NOTE. The Committee on Standard Specifications inserts the following table for temporary use to be replaced by one to be devised by the Committee of the American Society of Civil Engineers.

PERCENTAGE OF WATER FOR STANDARD MIXTURES.

Neat	1-1	1-2	1-3	1-4	1-5	Neat	1-1	1-2	1-3	1-4	1-5
18	12.0	10.0	9.0	8.4	8.0	33	17.0	13.3	11.5	10.4	9.6
19	12.3	10.2	9.2	8.5	8.1	34	17.3	13.6	11.7	10.5	9.7
20	12.7	10.4	9.3	8.7	8.2	35	17.7	13.8	11.8	10.7	9.9
21	13.0	10.7	9.5	8.8	8.3	36	18.0	14.0	12.0	10.8	10.0
22	13.3	10.9	9.7	8.9	8.4	37	18.3	14.2	12.2	10.9	10.1
23	13.7	11.1	9.8	9.1	8.5	38	18.7	14.4	12.3	11.1	10.2
24	14.0	11.3	10.0	9.2	8.6	39	19.0	14.7	12.5	11.2	10.3
25	14.3	11.6	10.2	9.3	8.8	40	19.3	14.9	12.7	11.3	10.4
26	14.7	11.8	10.3	9.5	8.9	41	19.7	15.1	12.8	11.5	10.5
27	15.0	12.0	10.5	9.6	9.0	42	20.0	15.3	13.0	11.6	10.6
28	15.3	12.2	10.7	9.7	9.1	43	20.3	15.6	13.2	11.7	10.7
29	15.7	12.5	10.8	9.9	9.2	44	20.7	15.8	13.3	11.9	10.8
30	16.0	12.7	11.0	10.0	9.3	45	21.0	16.0	13.5	12.0	11.0
31	16.3	12.9	11.2	10.1	9.4	46	21.3	16.1	13.7	12.1	11.1
32	16.7	13.1	11.3	10.3	9.5						

	1 to 1	1 to 2	1 to 3	1 to 4	1 to 5
Cement..	500	333	250	200	167
Sand ...	500	666	750	800	833

TIME OF SETTING.

21.—*Method.*—For this purpose the Vicat Needle, which has already been described in paragraph 17, should be used.

22.—In making the test, a paste of normal consistency is molded and placed under the rod (*L*), Fig. 2, as described in paragraph 18; this rod, bearing the cap (*D*) at one end and the needle (*H*), 1 mm. (0.039 in.) in diameter, at the other, weighing 300 gr. (10.58 oz.). The needle is then carefully brought in contact with the surface of the paste and quickly released.

23.—The setting is said to have commenced when the needle ceases to pass a point 5 mm. (0.20 in.) above the upper surface of the glass plate, and is said to have terminated the moment the needle does not sink visibly into the mass.

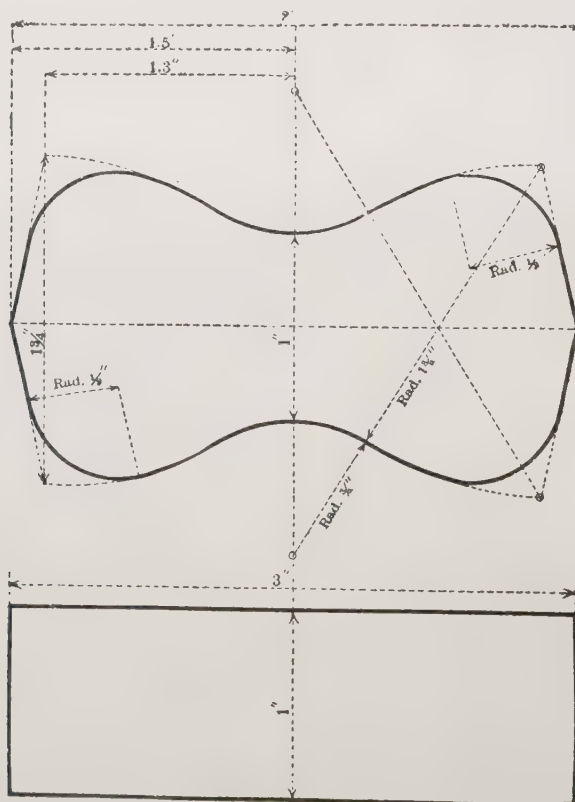
24.—The test pieces should be stored in moist air during the test; this is accomplished by placing them on a rack over water contained in a pan and covered with a damp cloth, the cloth to be kept away from them by means of a wire screen; or they may be stored in a moist box or closet.

25.—Care should be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point reduces the area and tends to increase the penetration.

26.—The determination of the time of setting is only approximate, being materially affected by the temperature of the mixing water, the temperature and humidity of the air during the test, the percentage of water used, and the amount of molding the paste receives.

STANDARD SAND.

27.—For the present, the Committee recommends the natural sand from Ottawa, Ill., screened to pass a sieve having 20 meshes per linear inch and retained on a sieve having 30 meshes per linear inch; the wires to have diameters of 0.0165 and 0.0112 in., respectively, *i. e.* half the width of the opening in each case. Sand having passed the No. 20 sieve shall be considered standard when not more than 1 per cent passes a No. 30 sieve after one minute continuous sifting of a 500-gram sample.*



DETAILS FOR BRIQUETTE.

FIG. 3.

* The Sandusky Portland Cement Company, of Sandusky, Ohio,* has agreed to undertake the preparation of this sand and to furnish it at a price only sufficient to cover the actual cost of preparation.

FORM OF BRIQUETTE.

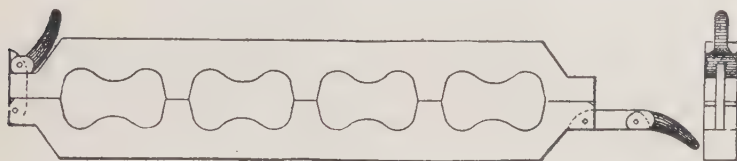
28.—While the form of the briquette recommended by a former Committee of the Society is not wholly satisfactory, this Committee is not prepared to suggest any change, other than rounding off the corners by curves of $\frac{1}{2}$ -in. radius, Fig. 3.

MOLDS.

29.—The molds should be made of brass, bronze or some equally non-corrodible material, having sufficient metal in the sides to prevent spreading during molding.

30.—Gang molds, which permit molding a number of briquettes at one time, are preferred by many to single molds; since the greater quantity of mortar that can be mixed tends to produce greater uniformity in the results. The type shown in Fig. 4 is recommended.

31.—The molds should be wiped with an oily cloth before using.



DETAILS FOR GANG MOULD.

FIG. 4.

MIXING.

32.—All proportions should be stated by weight; the quantity of water to be used should be stated as a percentage of the dry material.

33.—The metric system is recommended because of the convenient relation of the gram and the cubic centimeter.

34.—The temperature of the room and the mixing water should be as near 21° C. (70° F.) as it is practicable to maintain it.

35.—The sand and cement should be thoroughly mixed dry. The mixing should be done on some non-absorbing surface, preferably plate glass. If the mixing must be done on an absorbing surface it should be thoroughly dampened prior to use.

36.—The quantity of material to be mixed at one time depends on the number of test pieces to be made; about 1,000 gr. (35.28 oz.) makes a convenient quantity to mix, especially by hand methods.

37.—*Method.*—The material is weighed and placed on the mixing table, and a crater formed in the center, into which the proper percentage of clean water is poured; the material on the outer edge is turned into the crater by the aid of a trowel. As soon as the water has been absorbed, which should not require more than one minute, the operation is completed by vigorously kneading with the hands for an additional $1\frac{1}{2}$ minutes, the process being similar to that used in kneading dough. A sand-glass affords a convenient guide for the time of kneading. During the operation of mixing, the hands should be protected by gloves, preferably of rubber.

MOLDING.

38.—Having worked the paste or mortar to the proper consistency, it is at once placed in the molds by hand.

39.—*Method.*—The molds should be filled immediately after the mixing is completed, the material pressed in firmly with the fingers, and smoothed off with a trowel, without mechanical ramming; the material should be heaped up on the upper surface of the mold, and, in smoothing off, the trowel should be drawn over the mold in such a manner as to exert a moderate pressure on the excess material. The mold should be turned over and the operation repeated.

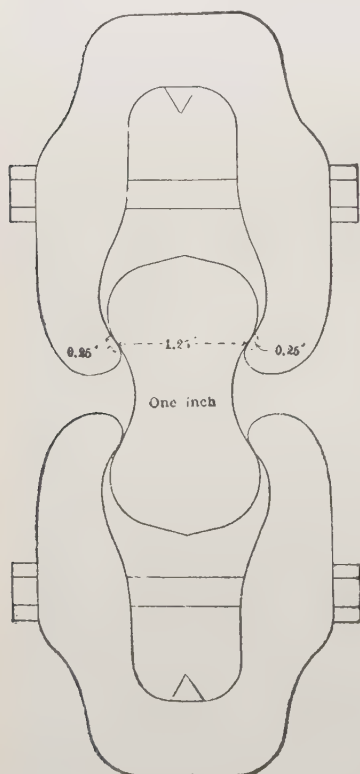
40.—A check upon the uniformity of the mixing and molding is afforded by weighing the briquettes just prior to immersion, or upon removal from the moist closet. Briquettes which vary in weight more than 3 per cent from the average should not be tested.

STORAGE OF THE TEST PIECES.

41.—During the first 24 hours after molding, the test pieces should be kept in moist air to prevent them from drying out.

42.—A moist closet or chamber is so easily devised that the use of the damp cloth should be abandoned if possible. Covering the test pieces with a damp cloth is objectionable, as commonly used, because the cloth may dry out unequally, and in consequence the test pieces are not all maintained under the same condition. Where a moist closet is not available, a cloth may be used and kept uniformly wet by immersing the ends in water. It should be kept from direct contact with the test pieces by means of a wire screen or some similar arrangement.

43.—A moist closet consists of a soapstone or slate box, or a metal-lined wooden box—the metal lining being covered with felt and this felt kept wet. The bottom of the box is so constructed as to hold water, and the sides are provided with cleats for holding glass shelves on which to place the briquettes. Care should be taken to keep the air in the closet uniformly moist.



FORM OF CLIP.
FIG. 5.

COPPER BOILER

Boiler to be made of sheet copper weighing 22 oz. per sq. ft., tinned inside.
All seams to be lapped where possible. Hard solder to be used only

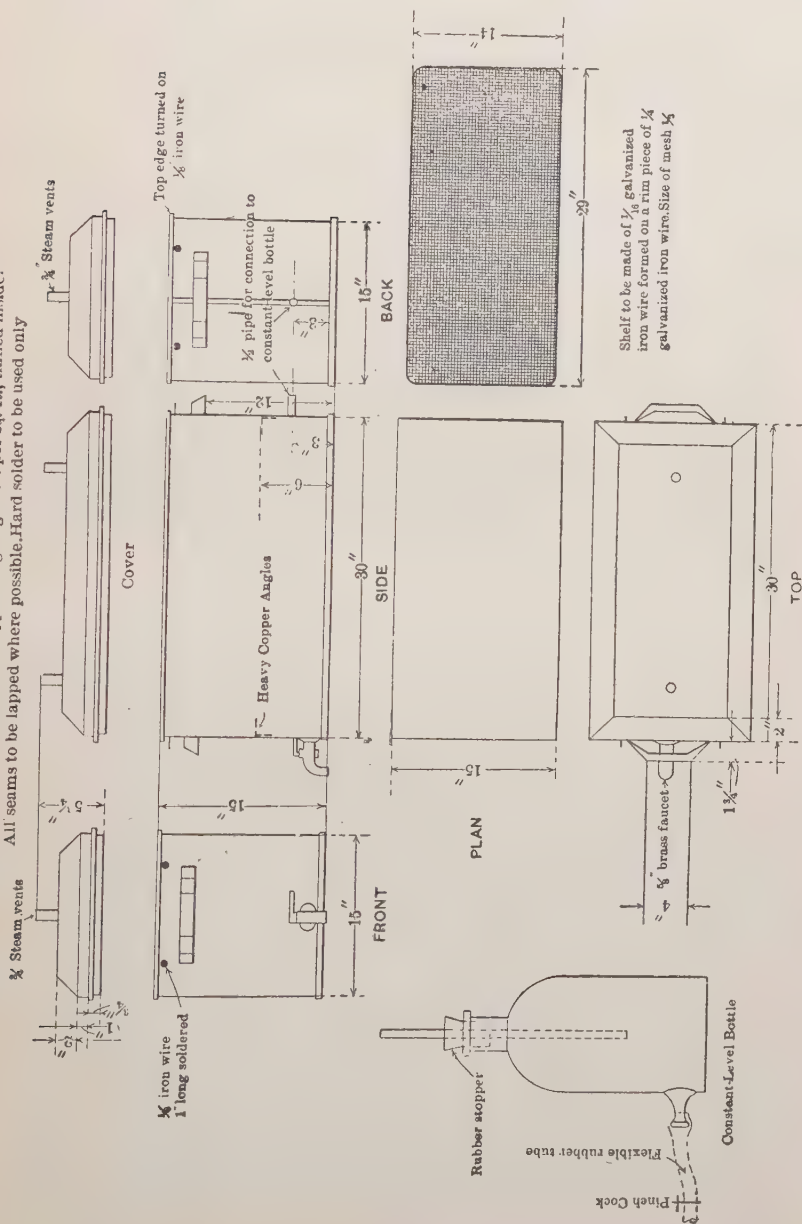


FIG. 6.

44.—After 24 hours in moist air, the test pieces for longer periods of time should be immersed in water maintained as near 21° C. (70° F.) as practicable; they may be stored in tanks or pans, which should be of non-corrodible material.

TENSILE STRENGTH.

45.—The tests may be made on any standard machine. A solid metal clip, as shown in Fig. 5, is recommended. This clip is to be used without cushioning at the points of contact with the test specimen. The bearing at each point of contact should be $\frac{1}{4}$ in. wide, and the distance between the center of contact on the same clip should be $1\frac{1}{4}$ ins.

46.—Test pieces should be broken as soon as they are removed from the water. Care should be observed in centering the briquettes in the testing machine, as cross-strains, produced by improper centering, tend to lower the breaking strength. The load should not be applied too suddenly, as it may produce vibration, the shock from which often breaks the briquette before the ultimate strength is reached. Care must be taken that the clips and the sides of the briquette be clean and free from grains of sand or dirt, which would prevent a good bearing. The load should be applied at the rate of 600 lbs. per minute. The average of the briquettes of each sample tested should be taken as the test, excluding any results which are manifestly faulty.

CONSTANCY OF VOLUME.

47.—*Methods.*—Tests for constancy of volume are divided into two classes: (1) normal tests, or those made in either air or water maintained at about 21° C. (70° F.), and (2) accelerated tests, or those made in air, steam or water at a temperature of 45° C. (115° F) and upward. The test pieces should be allowed to remain 24 hours in moist air before immersion in water or steam, or preservation in air.

48.—For these tests, pats about $7\frac{1}{2}$ cm. (2.95 ins.) in diameter, $1\frac{1}{4}$ cm. (0.49 in.) thick at the center, and tapering to a thin edge, should be made, upon a clean glass plate [about 10 cm. (3.94 ins.) square], from cement paste of normal consistency.

49.—*Normal Test.*—A pat is immersed in water maintained as near 21° C. (70° F.) as possible for 28 days, and observed at intervals. A similar pat, after 24 hours in moist air, is maintained in air at ordinary temperature and observed at intervals.

50.—*Accelerated Test.*—A pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel, for 5 hours. The apparatus recommended for making these determinations is shown in Fig. 6.

51.—To pass these tests satisfactorily, the pats should remain firm and hard, and show no signs of cracking, distortion or disintegration.

52.—Should the pat leave the plate, distortion may be detected best with a straight-edge applied to the surface which was in contact with the plate.

REPORT OF COMMITTEE D ON STANDARD SPECIFICATIONS FOR PAVING AND BUILDING BRICK.

During the past four years your Committee on Standard Specifications for Paving and Building Brick, besides holding regular meetings, has conducted several lines of investigation, and has studied all available information on the subject. The Committee fully realizes the impracticability, at the present state of our knowledge of the subject, of preparing permanent specifications to cover the testing of building brick of all grades and from all sections of the country. It has, however, prepared the following proposed specifications to cover the commercial building brick usually met with.

Your Committee desires to state that it fully realizes the importance of a fire test for brick for certain types of construction. It has decided, however, that the work so far done on this subject has not reached a sufficient degree of refinement for useful specifications, and it earnestly hopes that further investigations will be conducted.

PROPOSED STANDARD SPECIFICATIONS FOR BUILDING BRICK.

Selection of Samples.—For the purpose of tests, brick shall be selected by some disinterested and experienced person to represent the commercial product. All brick shall be carefully examined, and their condition noted before being subjected to any test.

Transverse Test.—At least five bricks shall be tested, laid flatwise with a span of 7 ins., and with the load applied at mid-span. The knife edges shall be slightly curved in the direction of their length. Steel bearing plates, about $\frac{1}{4}$ in. thick and $1\frac{1}{2}$ ins. wide, may be placed between the knife edges and the brick. The use of a wooden base-block, slightly rounded transversely across its top, upon which to rest the lower knife edges, is recommended.

(See Fig. 1.) The modulus of rupture shall be obtained by the following formula:

$$R = \frac{3We}{2bd^2}$$

in which e is the distance between supports in inches, b is the breadth and d depth of the brick in inches, and W is the load in pounds at which the brick failed.

The half bricks resulting from the transverse test shall be used for the compression and absorption tests. One half shall be crushed in its dry condition; the other half shall be used for the absorption test and crushed while in its wet condition. No specimens shall be used if any part of the line of fracture is more than 1 in. from the center line.

Compression Test.—Compression tests shall be made on half bricks resulting from the transverse test. The bricks shall be bedded flatwise on blotting paper, heavy fibrous building paper, or heavy felt, to secure a uniform bearing in the testing machine. In case the bricks have uneven bearing surfaces, they shall be bedded in a thin coat of plaster of Paris. For the dry test, before applying the plaster of Paris, the bearing surfaces of the brick shall receive a coat of shellac. The machine used for compression tests shall be equipped with spherical bearing blocks. The breaking load shall be divided by the area in compression, and the results reported in pounds per square inch.

Absorption Test.—At least five half bricks shall be first thoroughly dried to constant weight, at a temperature of from 200° to 250° F., weighed, and then placed on their face in water to a depth of 1 in. in a covered container. The bricks shall be weighed at the following intervals: one-half hour, six hours, and forty-eight hours. Superfluous moisture shall be removed before each weighing. The absorption shall be expressed in terms of the dry weight, and the balance used must be accurate to 5 grams.

Freezing and Thawing Tests.—In case the freezing and thawing test is desired, at least five bricks shall be thoroughly saturated by immersion in cold water, which shall be raised to 200° F. in thirty minutes, and then allowed to cool. The specimens shall be immersed in ice water for not less than one hour,

weighed, then transferred to the refrigerator and supported in such a manner that all faces will be exposed. The specimen shall be subjected to a temperature of less than 15° F. for at least five hours; then removed and placed in water at a temperature of not less than 150° F., nor more than 200° F., for one hour. This operation shall be repeated twenty times, after which the bricks, still saturated, shall be weighed again. The character of the bricks shall be noted before and during the test, and all visible

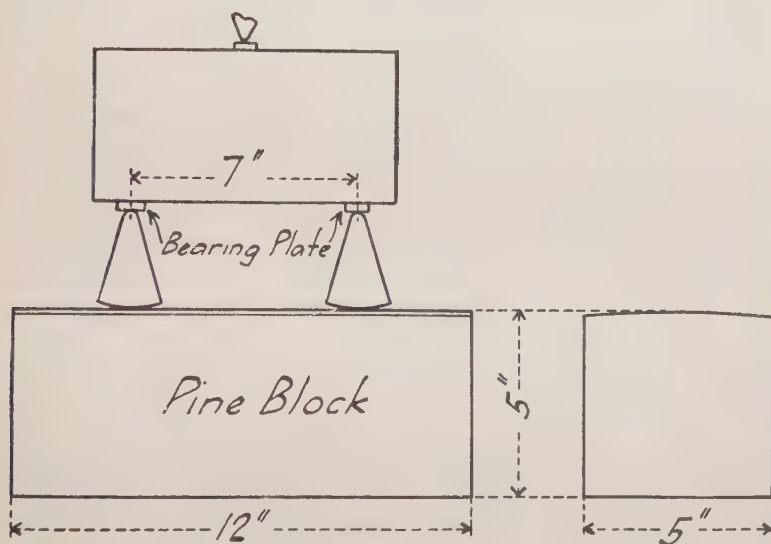


FIG. 1.

changes recorded. Immediately on completion of this test, the samples are to be thoroughly dried and subjected to the transverse and compression tests.

Requirements.—The following requirements shall be met.

The modulus of rupture shall be as follows:

	Average, lbs.	Minimum, lbs.
For samples thoroughly dry	400	325
For samples thoroughly saturated	275	225
For samples subjected to freezing and thawing process	275	225

The ultimate compressive strength shall be as follows:

	Average, lbs. per sq. in.	Minimum, lbs. per sq. in.
For samples thoroughly dry	3,000	2,500
For samples thoroughly saturated	2,500	2,000
For samples subjected to freezing and thawing process	2,500	2,000

The absorption shall not average higher than 15 per cent., and in no case shall it exceed 20 per cent.

The freezing and thawing tests shall not cause cracking or serious spalling in any of the bricks tested, nor cause serious disintegration of the material.

Respectfully submitted on behalf of the Committee,

E. W. LAZELL,
Secretary.

LOGAN WALLER PAGE,
Chairman.

DISCUSSION.

MR. J. E. HOWARD.—I should like to make some remarks Mr. Howard.
in regard to the absorption tests, the object of which, of course, is to ascertain the maximum quantity of water which can be absorbed. In experimenting along this line we have taken bricks and placed them in water where they were kept for different periods up to a week's time, then after a week's immersion boiled the brick, which last operation increased the amount of water absorbed. The final volume absorbed did not, however, account for all the voids that were present as shown by the density of the ground material, determined by a Schuman volumeter. In considering methods of testing, to incorporate in brick specifications, it would seem desirable to use methods which will not leave interior voids in the brick unaccounted for.

In regard to the proposed specifications for compressive strengths, they seem to be set absurdly low, excepting for light-hard brick. The test of an exceptionally strong brick gave a compressive resistance of over 38,000 lbs. per sq. in., but such strong material is not expected to be called for in specifications. However, values ranging beyond 3,000 to 5,000 lbs. per sq. in. are found very frequently in light-hard brick, and such values are very low for other kinds of brick; crushing strengths from 8,000 to 15,000 lbs. per sq. in. are by no means unusual.

MR. R. L. HUMPHREY.—I think the plan of allowing speci- Mr. Humphrey.
fications to go into print in order that we may have something to pin our arguments to is an excellent one. In my opinion some of the methods reported by the Committee, while they may answer for the present, are very unsatisfactory. For instance, in finding the compressive strength of a brick laid flatwise, it should be remembered that some kinds of brick will flow under the testing machine as the load is increased. I do not believe that the compressive strength of a brick has any direct bearing on its quality. It certainly is not an indication of any value in ordinary constructive work. I think the transverse test is much more valuable as an indication of the quality of the brick, although the method

Mr. Humphrey. recommended by the Committee of testing the brick flat is open to question.

In the matter of absorption, I believe the question of time is far more important than any other point. I think that if specifications would limit the amount of absorption in a given time, that would have a great bearing on the grade of brick submitted; a very excellent way of studying the quality of a brick being to examine the curve of the absorption plotted against the time. The structure of a brick may be such that it will have a slower rate of absorption than another, but a higher limit of absorption. The average person is apt to think that brick is brick; whereas in going over the country the widest variations in grades of brick are found to exist.

In drawing specifications to apply to the product in general, very serious difficulties are apt to be encountered, and it may be desirable to so modify the specifications that different grades of brick will be provided for. These specifications, I think, are too low for many of the bricks in our Eastern states in which we have good bricks. They are too high for bricks in the South-west, where the clay is of a sandy character or possesses other qualities that make the manufacture of equally good bricks difficult or impossible. Further investigations are needed to obtain the data requisite for specifications.

Mr. Page. **MR. L. W. PAGE.**—With reference to the point that Mr. Howard brought out, which is a very interesting one, I think that the method he suggests is rather the determination of the porosity than the absorption. In reply to the question raised by Mr. Humphrey, the Committee has stated clearly that it fully realizes the difficulty to be encountered in drawing specifications to meet brick under all conditions, nor did it for a moment undertake such a plan. I would say further in reply to Mr. Humphrey that the Committee anticipates conducting several lines of investigation to determine certain doubtful points.

Mr. Howard. **MR. HOWARD.**—I would say that porosity and absorption mean the same thing in very soft brick, and there is some practical difficulty in other brick in discriminating between what belongs to absorption, and what to porosity.

Mr. Woolson. **MR. I. H. WOOLSON.**—I want to say one word. If a brick breaks out of line, say $\frac{1}{2}$ in., it is very easy to trim the edge with a

brick chisel and get it to a condition where it is perfectly fair to make a compression test when the average of five is to be taken. Mr. Woolson.

MR. A. N. TALBOT.—I think it may be said that the Committee had in mind two points: First, to make these tests as simple as possible, since they are to be made all over the country by different laboratories and may be handled in ways that are not perhaps as scientific as those used by investigators; second, if we have in general use a class of material which is not of the highest grade but which suits most purposes, it would be folly for us to make specifications which would reject it; that is, it would not be wise to require a crushing strength of 10,000 lbs. per sq. in., even though much of the material that is available will give this strength. Mr. Talbot.

Now as to the absorption test; the three periods of time given for the absorption test, $\frac{1}{2}$ hour, 6 hours, and 48 hours were selected as periods within the working day of the ordinary laboratory, which would give in some way the rate of absorption. More work might be done by an investigator who is studying the properties or qualities of a particular brick. The Committee appreciates that the absorption of water will continue in some kinds of brick for a considerable length of time; but the Committee feels that the standing of a brick in which this absorption continues indefinitely will not be affected by placing the time at 48 hours. In other words, the limit of 48 hours will determine whether a brick should be thrown out, as well as may be done under any specifications of this character. If there is anything in the quality of the brick which indicates that it does continue to absorb, the three determinations would assist the tester in deciding whether the brick should have a further test.

In regard to the cross-bending test, I know that there is a difference of practice as to whether the brick shall be placed flatwise or upon edge. The practice with which I am familiar is to place the brick on edge; that has been adopted particularly in testing a line of brick which is not considered by these specifications, paving brick. It was found, however, that in New York and Philadelphia, and I think in one other city, ordinances already in existence provide for testing the brick flatwise. This form of test is reasonable, especially as the cross-bending strength of the brick has a great deal to do with the strength of piers and walls.

Mr. Talbot. Again, in reference to the compression test, the Committee felt that it was desirable to take broken brick from the transverse test in order to save expense, the trouble and expense being considerable; and the requirement that any point in the line of fracture should be not more than 1 in. from the center line of the brick was inserted in order to secure a piece as nearly regular as possible, the intention being that the brick shall be discarded and other samples secured in case regular pieces are not found.

REPORT OF COMMITTEE E ON PRESERVATIVE COATINGS FOR STRUCTURAL MATERIALS.

The work of the Committee has continued along the lines presented in the last annual report in following the paint tests undertaken by the Committee.

The results of the tests at Havre de Grace show that in nearly every case the paints on both the panels and the bridge proper are affording excellent protection after a little more than two and one-half years' exposure. The report of the last inspection made in March of this year is abstracted as follows:

MR. S. S. VOORHEES,

Chairman, Committee E, American Society for Testing Materials,
Washington, D. C.

Dear Sir:

The last inspection of the Havre de Grace bridge made in March of this year showed no general depreciation in any marked way since last year's inspection of the various protective coatings under test, except their natural deterioration from time. The paint films showed the effect of time generally in the loss of any original luster or gloss, rather than in actual disintegration at this time, and it is expected that another year will permit some classification due to marked deterioration. Some differentiation in particular paints can already be made between the panels covered with the same coating at different rates of spreadings, but it is too early to draw any positive conclusions therefrom.

As stated above, another year should permit definite conclusions in many respects. Only the care with which the panels were treated will allow, when failure thereof is positive, accurate comparison therewith in the case of identical paints used on the large surface of the bridge proper.

(Signed) W. A. AIKEN,
Chairman, Sub-Committee on Inspection.

It is the intention of the Committee to have detailed photographic records made of the panels as soon as the condition of the paint films warrant such reproduction. It is also the intention to have the paint removed from one of the panels in each set by a paint remover and a photographic record and careful examination made of the surface of the metal. The condition of the steel

under the paint film will be noted with much interest in the light of recent laboratory experiments showing the different actions of certain pigments on corrosion. The information gained from this practical service test will be of great importance in determining the value of the laboratory test.

The last inspection of the wooden panels at Atlantic City furnishes some interesting information. It should be stated, however, that Committee E has only acted in an inspecting capacity for this set of tests. The report of the Sub-Committee on Inspection is as follows:

MR. S. S. VOORHEES,

Chairman, Committee E, American Society for Testing Materials,
Washington, D. C.

Dear Sir:

An inspection was made March 27, 1909, at Atlantic City by the Sub-Committee on Inspection of Wooden Panels Test Fence. The following members of the Sub-Committee were present: Messrs. Aiken Job, Sabin, Voorhees; Dr. Dudley and other members of Committee E were also present.

It was found that the lithopone panels had completely failed, and authority was given the Paint Manufacturers' Association to remove panels, formulas 21 to 28 inclusive, and substitute other formulas which the Association may wish to test. The composition of the lithopone formulas ranged from 100 per cent. lithopone to 60 per cent. lithopone with various other pigments. In most cases the coating had so completely perished that the bare board was visible in spots, and on the rest of the surface the life of the coating had completely gone. The time of exposure was about one year, and the corresponding panels on both sides of the fence had failed about equally.

The Sub-Committee found that all of the pure white lead panels chalked considerably and were in less efficient condition in this respect than many of the composition paints. The relative efficiency of the latter will be reported from time to time.

It was found in general that the tints were in considerably better condition than the corresponding whites, and that the results upon cypress and yellow pine were often unsatisfactory owing to the character of the wood, and in order to facilitate close comparison at future inspections, the Paint Manufacturers' Association was authorized to remove the tints upon cypress and yellow pine and to group the whites together in such location that close examination can be made.

At the annual meeting of the Society it is hoped that inspection will be made by Committee E.

(Signed) ROBERT JOB,
Chairman, Sub-Committee.

This series of exposures has confirmed the statement made in last year's report, that the results will be of much value in simplifying a further set of tests to be undertaken entirely under the direction of Committee E.

A further investigation of the Committee has been undertaken to standardize the tests employed in the examination of linseed oil, so that when the tests and methods required to determine the quality of linseed oil are satisfactorily established, specifications for this material may be prepared.

To this end a sub-committee of eight was appointed as follows:

Gustave W. Thompson, Chairman, Chemist, National Lead Company, Brooklyn, N. Y.

S. S. Voorhees, Engineer of Tests, U. S. Geological Survey, Washington, D. C.

C. N. Forrest, New York Testing Laboratory, Maurer, N. J.

Parker C. McIlhiney, Consulting Chemist, New York City, N. Y.

J. F. Walker, Chemist, Clements and Son Company, Philadelphia, Pa.

P. H. Walker, U. S. Bureau of Chemistry, Washington, D. C.

A. H. Sabin, Chemist, Flushing, N. Y.

Augustus H. Gill, Massachusetts Institute of Technology, Boston, Mass.

The chairman of this Sub-Committee has outlined and carried through this work with great care, and the results obtained from the different laboratories have added materially to our knowledge of the constants of commercially pure raw linseed oil. The data are of such value that the report of the Sub-Committee will be presented at this meeting, with a view of publication in full in the Proceedings.

REPORT OF SUB-COMMITTEE ON LINSEED OIL.

This Sub-Committee was appointed at a meeting of Committee E at the Annual Convention of the Society in 1908. It was considered desirable that the study of linseed oil should be undertaken systematically with the idea that such study would assist in the preparation of proper specifications for the purity and for the quality of linseed oil, and ultimately lead to better and more exact knowledge of how linseed oil should be used in order to

obtain the best results. This Committee, after considering carefully what was practicable, decided on the following plan for the year now ending: Samples of linseed of known purity were to be obtained and specifications for analysis prepared. Then, portions of these samples were to be distributed among competent chemists and the results of their examinations reported. Other portions of the samples were to be reserved for future work, particularly on points on which the testing chemists had disagreed. How far the work planned was carried out may be judged from the present report.

Four producers of linseed oil consented to allow samples of oil to be taken at their mills and contributed the oil needed for this work. These producers were the National Lead Co., the American Linseed Co., Hirst and Begley, and the Archer-Daniels Co.

Three "committees on sampling" were appointed to superintend the sampling of this oil. Their personnel is as follows:

New York City.—Parker C. McIlhiney, Chairman; A. H. Sabin, C. N. Forrest, R. E. Doolittle.

Chicago.—Edward Gudeman, Chairman; R. Smith, A. L. Winton.

St. Paul.—A. S. Mitchell, Chairman; Rodney M. West, F. G. Smith.

The specifications adopted for testing the samples are as follows:

SPECIFICATIONS FOR TAKING SAMPLES.

(a) *Sample to Represent.*—The sample shall represent the product of a given factory at a given time, as it comes from the presses (or what would correspond thereto), and be immediately filtered through paper.

(b) *Supervision.*—These samples shall be taken under the supervision of committees of three or more persons, which committees, respectively, shall certify that they have superintended the taking of their samples, describing the place, etc., at which they were taken, and the samples so taken shall be forwarded by express to the chairman of the Sub-Committee, 129 York Street, Brooklyn.

(c) *Quantity of Sample.*—About twenty gallons of the oil shall be placed in a clean receptacle and, after thorough agitation, shall be filled, when filtered, into forty clean quart bottles and two 5-gallon cans, which shall be properly stoppered, sealed and labeled. In addition to sealing, the cans should be soldered hermetically. The oil from the presses, or

their equivalent, can be filtered and put in clean barrels, sealed and shipped to the laboratory of the Chairman of the Supervising Committee for bottling, after thorough mixing, if so desired. The bottles and cans will be furnished by the Sub-Committee. The bottles should be stoppered with clean sunk stoppers and sealed with a hot mixture of gelatine 11 oz., water 6 fluid oz., and glycerine 1 fluid oz., and when cold should be sealed with strip labels to be furnished by the Sub-Committee. The labels for the bottles will also be furnished by the Sub-Committee.

(d) *The Seed Used*.—A quart of the seed used shall be placed in a clean quart Mason jar, sealed and labeled and forwarded with the oil samples to the chairman of the Sub-Committee.

(e) *Filtering*.—The oil shall be filtered through a small filter-press using paper-filtering medium immediately after being taken from the presses or their equivalent, and before the oil becomes cold.

These sampling specifications could not be followed out entirely, as the reports of the sampling committees will indicate. There is every reason to believe, however, that the samples are valid, and all that they are represented to be. We give here the reports of the sampling committees:

NEW YORK, May 21, 1909.

MR. GUSTAVE W. THOMPSON, *Chairman*,
Brooklyn, N. Y.

Dear Sir:

On February 2 a committee consisting of Prof. A. H. Sabin, Mr. R. E. Doolittle, Mr. C. N. Forrest, and myself visited the Atlantic Mill of the National Lead Company in Brooklyn and there witnessed the preparation of forty 1-quart samples of linseed oil and also two 5-gallon-can samples, together with two 1-quart samples of the seed from which the oil was manufactured. The samples of seed were taken by the automatic sampler in regular use in the mill, which sampled the seed going to one of the sets of rolls which were used to grind the seed. From the grinding rolls the seed went to a heating tub in which it was heated by steam, and from this heater it was pressed in hydraulic presses. From the hydraulic presses the oil was taken to a small hand-filter press in which it was filtered through paper. This hand-filter press did not work perfectly and in consequence the oil obtained was not perfectly filtered, but was slightly turbid, and the samples were bottled with this slight turbidity evenly distributed through it.

Every facility was afforded to your Committee for making a complete identification of the oil and seed, and the Committee kept the process under continuous inspection, so that there can be no doubt that the oil of which the samples were prepared at that time was actually obtained from the seed of which a sample was also taken.

Respectfully,
(Signed)

PARKER C. McILHINEY.

CHICAGO, February 10, 1909.

MR. G. W. THOMPSON, *Chairman*,
Brooklyn, N. Y.

Dear Sir:

As per your request, Prof. R. Smith, Dr. A. L. Winton, and myself obtained for you authentic samples of the linseed oil made at the Hirst and Begley Mill, Chicago, Ill., and the American Linseed Company Mill, South Chicago.

Hirst and Begley Mill.—The samples, taken February 3, 1909, consist of 20 gallons of linseed oil and 1 quart of linseed, representing seed from which oil was pressed. It was not possible for the Committee to filter-press the oil at the mill. The sample represents the filtered oil, as filtered through the mill press. As the Committee were present during pressing, and watched the filtering, and run of oil into the tank, there is no doubt in their minds that this sample is pure raw linseed oil. The process in use at the Hirst and Begley Mill is that of direct pressure with Anderson expellers. The oil runs from the presses comparatively cold, the ground seed not being cooked or steamed as in the hydraulic process. The foots separated in the filter press are continually returned to be treated as fresh seed. The oil is bright, clear, nearly odorless and tasteless.

American Linseed Company Mill.—The samples, taken February 6, 1909, consist of 20 gallons of linseed oil and 1 quart of linseed, representing average of seed from which oil was pressed. It was impossible for the Committee to filter-press the oil at the mill. The sample represents the filtered oil, as filtered through the mill presses. The Committee feels assured that the samples of oil taken are pure and represent the crude linseed oil made by this process. The process used at the South Chicago mill of the American Linseed Company is that of direct extraction with naphtha. It is not possible to follow this process directly, as the time from linseed to linseed oil is from four to five days. The system involves extraction in batteries of percolators. The oil from the extraction tank is then run into the evaporators and the naphtha is separated. The oil from the pans is purified by having the small amount of foots separated in a centrifugal machine, which also takes out some of the water due to the use of steam in the separation of the naphtha. The oil is then heated and filtered through cloth. The sample of oil taken is the filtered oil as it comes from the mill filters. At this mill special grades of linseed oil are made, and the raw oil taken is not a commercial product. Their examination of the plant leads the Sampling Committee to the conclusion that the sample of oil taken is pure linseed oil. The sample of oil was taken from the pump to the refinery. A superficial examination of this mill justifies the Sampling Committee in concluding that nothing but straight linseed oil is made at this plant, and that the samples taken represent a fair average of raw linseed oil as made by the naphtha extraction process.

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At both mills, that of Hirst and Begley, and that of the American Linseed Company, every facility was offered your Sampling Committee to assure themselves that nothing but straight linseed is used and that the oils are straight, pure linseed oils.

(Signed) EDWARD GUDEMAN, *Chairman*.

ST. PAUL, MINN., February 19, 1909.

MR. GUSTAVE W. THOMPSON, *Chairman*,
Brooklyn, N. Y.

Dear Sir:

On Saturday last Mr. Rodney M. West, Assistant State Analyst of Minnesota, Mr. F. G. Smith, Assistant Chemist, Food and Drug Inspection Laboratory, Bureau of Chemistry, U. S. Department of Agriculture, and myself visited the works of the Archer-Daniels Linseed Co. at Minneapolis, and secured the forty 1-quart samples of linseed oil requested, and also two 5-gallon cans, together with one quart of the seed from which the oil was manufactured. The sample of seed was secured by gathering from 1 to 2 ounces every five minutes from each of the four roller mills which were feeding one "cooker," for a period of an hour and a quarter. These small samples were mixed into a composite sample, from which the quart was taken.

After allowing for the time necessary for the seed, which we saw milled, to pass through the "cooker," this hot meal was pressed in the usual manner, using a maximum pressure of slightly above 3,000 lbs. per sq. in. The oil from the presses was received in an empty scale-tank in the basement, and pumped to a clean tank upon the third floor, whence it filtered by gravity through one of the large presses from which all slimes had been removed. The middle run from this filtration was secured by intercepting the stream from the filter, and was placed in 10-gallon cans. It was bottled at the laboratory three days later.

This oil has not been filtered while hot through paper, as directed, but has received, as stated, but one filtration through canvas. It is customary at the works to filter all oil twice through canvas, and the second filtration is done upon filters which contain some sludge. A filter does not reach its maximum efficiency until it has been in use for a short period. It was impossible to give this oil two filtrations, as two large presses could not be cleaned and made available. It is customary to perform the final clarification by sedimentation in the storage.

As the samples required amount to 20 gallons, an amount largely in excess of that anticipated by the Archer-Daniels firm, it is not improbable that a bill will be rendered for this oil.

Kindly advise me as to the disposition of the samples taken. I would suggest that they be not shipped in one lot in the box as sent, for the reason that three of the empty bottles were broken in transit and the weight would be excessive when filled.

Respectfully,

(Signed) A. S. MITCHELL, Chief, St. Paul Laboratory.

In order to enlist general support in our work, about 150 letters were sent to chemists throughout the country, and the following circular letter was distributed:

AMERICAN SOCIETY FOR TESTING MATERIALS.

February 9, 1909.

Dear Sir:

This Society's Committee E (on Preservative Coatings) has taken up the subject of the so-called Constants of Linseed Oil. Four samples of known purity are being prepared, taken from different mills of the country, and they will be ready for distribution in the latter part of February for analysis. This entire matter has been placed in the hands of the undersigned as a Sub-Committee. The tests decided on as essential are:

1. Specific Gravity.
2. Turbidity and Fouts.
3. Breaking Test.
4. Moisture and Volatile Matter.
5. Ash.
6. Drying Test on Glass.
7. Oxygen Absorption.
8. Acid Number.
9. Saponification Number.
10. Unsaponifiable Matter.
11. Liebermann-Storch Test.
12. Refractive Index.
13. Acetyl Value.
14. Hexabromide Test.
15. Iodine Number.

Specifications for analytical work are now being prepared. It is very desirable that this work should be done in the most thorough and scientific manner possible, and that no one undertake it except with that understanding. The results should be forwarded to the Chairman of the Sub-Committee by May 20, 1909.

Will you volunteer to test these samples? The results will be published in the report of the American Society for Testing Materials, and you will be given full credit for your part therein.

The result was that the following chemists consented to examine the samples and report on them.

1. G. W. Thompson, 129 York Street, Brooklyn, N. Y.
2. Parker C. McIlhiney, 7 East 42nd Street, New York City.
3. Percy H. Walker, Contracts Laboratory, U. S. Department of Agriculture, Bureau of Chemistry, Washington, D. C.

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4. A. H. Gill, Massachusetts Institute of Technology, Chemical Dept., Boston, Mass.
5. S. S. Voorhees, Engineer of Tests, Department of the Interior, U. S. Geological Survey, Washington, D. C.
6. Glenn H. Pickard, care of Spencer Kellogg & Co., Buffalo, N. Y.
7. Stillwell & Gladding, 181 Front Street, New York City.
8. Albert F. Seeker, Food & Drug Laboratory, U. S. Appraiser's Stores, New York City.
9. H. M. Loomis, Acting Chief of Food and Drug Inspection Laboratory, Arcade Annex, Seattle, Washington.
10. H. H. Knisely, 310 Worcester Building, Portland, Oregon.
11. A. J. Patten, Lansing, Michigan.
12. S. R. Mitchell, Agricultural College, New Mexico.
13. J. E. Greaves, Logan, Utah.
14. E. F. Ladd, Fargo, North Dakota..
15. L. M. Tolman, U. S. Department of Agriculture, Washington, D. C.
16. J. C. Dickerman, Madison, Wisconsin.
17. F. S. Kedsie, Lansing, Michigan.
18. H. H. Hanson, Orono, Maine.
19. J. S. Jones, Moscow, Idaho.
20. J. B. Lindsay, Amherst, Mass.
21. Paul Schweitzer, University of Missouri, Columbia, Mo.
22. Edward J. Shanley, Manhattan Building, Chicago, Ill.
23. C. B. Dudley, Pennsylvania Railroad, Altoona, Pa.
24. A. S. Mitchell, Old State House, St. Paul, Minn.
25. C. E. Waters, Bureau of Standards, Washington, D. C.
26. Arthur D. Little, 93 Broad Street, Boston, Mass.
27. Otto Eisenschimml, American Linseed Company, South Chicago, Ill.
28. Archer-Daniels Linseed Company, Minneapolis, Minn.
29. L. F. Williams, The North Carolina College of Agriculture and Mechanic Arts, West Raleigh, N. C.
30. M. H. Wickhorst, Engineer of Tests, Chicago, Burlington & Quincy Railroad, 209 Adams Street, Chicago, Ill.
31. A. P. Bjerregaard, Agricultural College, New Mexico.

Labels of the following form were used on these samples: .



AMERICAN SOCIETY FOR TESTING MATERIALS

SAMPLE OF

Taken at *Mill*

Remarks

.....

.....

.....1909

The undersigned committee certify that the sample described above and contained within has been taken under their supervision and according to directions of the above Society's sub-committee.

.....
Chairman

.....

.....

These samples, which were distributed about March 1, 1909, were labeled as follows:

AMERICAN SOCIETY FOR TESTING MATERIALS

Sample of
Linseed Oil

Taken at	National Lead Co.'s Atlantic Branch	Mill.
Remarks	Old Process.	Hot Pressed.

Feb. 2, 1909.

The undersigned committee certify that the sample described above and contained within has been taken under their supervision and according to directions of the above Society's sub-committee.

PARKER C. MCILHINEY, *Chairman.*
A. H. SABIN,
R. E. DOOLITTLE.

AMERICAN SOCIETY FOR TESTING MATERIALS

Sample of
Linseed Oil—Raw

Taken at	Hirst & Begley, Chicago,	Mill.
Remarks	Anderson—Expellers.	

Feb. 3, 1909.

The undersigned committee certify that the sample described above and contained within has been taken under their supervision and according to directions of the above Society's sub-committee.

EDWARD GUDEMAN, *Chairman.*
W. R. SMITH,
A. L. WINTON.

AMERICAN SOCIETY FOR TESTING MATERIALS

Sample of
Linseed Oil—Raw

Taken at	American Linseed Co., South Chicago,	Mill.
Remarks	Naphtha Process Oil Filtered through Mill Press.	

Feb. 6, 1909.

The undersigned committee certify that the sample described above and contained within has been taken under their supervision and according to directions of the above Society's sub-committee.

EDWARD GUDEMAN, *Chairman.*
W. R. SMITH,
A. L. WINTON.

AMERICAN SOCIETY FOR TESTING MATERIALS

Sample of
Raw Linseed Oil

Taken at	Archer-Daniels Linseed Co., Minneapolis,	Mill.
Remarks	Cleaned once through cloth in cleaned large filter-press at mill.	

Feb. 13, 1909.

The undersigned committee certify that the sample described above and contained within has been taken under their supervision and according to directions of the above Society's sub-committee.

A. S. MITCHELL, *Chairman.*
RODNEY M. WEST,
F. G. SMITH.

With each set of samples there was also sent a sample of C. P. bichromate of potassium, to be used in the standardization of the Hanus solution, and a sample of litharge to be used in the oxygen absorption test. The following letter was also sent to each analyst.

March 1, 1909.

CIRCULAR EXPLAINING THE PURPOSES AND PLANS IN
RELATION TO THE OBTAINING OF SAMPLES OF
LINSEED OIL OF KNOWN PURITY AND THEIR
EXAMINATION.

EXPLANATORY.

At the meeting of Committee E on Preservative Coatings at Atlantic City in June, 1908, the suggestion was made that a sub-committee be appointed for the purpose of having samples of linseed oil taken from different sources and having them tested by competent chemists, thereby determining the so-called Constants of Linseed Oil. Arrangements, accordingly, were made to have these samples taken at the Old Process Mills of the National Lead Company in New York and the Archer-Daniels Company in Minneapolis, also at the Hirst and Begley Mill (Anderson Process) in Chicago, and the American Linseed Oil Co.'s Mill (Extraction Process) in Chicago. Committees were appointed to take these samples in the several localities, according to specifications issued by this sub-committee. These samples have been taken and are being distributed for analysis. The tests to be applied are given in detail below. It is hoped that the reports on the examination of these samples will be ready for the annual meeting of the American Society for Testing Materials in June, next.

TESTS TO BE APPLIED.

After careful consideration, the following tests have been selected as those which the Sub-Committee asks to have applied. If there are other tests which the chemist cares to apply, he is at liberty to do so after these specified tests have been followed; in which case, he is requested to report to the Committee the results of his extra tests and the methods he has followed:

General.—All tests are to be made on oil which has been filtered at a temperature of between 60° and 80° F. through paper in the laboratory immediately before weighing out, except tests No. 2—Turbidity and Fouts, No. 4—Moisture and Volatile Matter and No. 5—Ash. The sample should be thoroughly agitated before the removal of a portion for filtration or analysis.

1. *Specific Gravity.*—Use a pycnometer, accurately standardized and having a capacity of at least 25 c.c., making a test at 25° C., water being 1 at 25° C., and another test at 15.5° C., water being 1 at 15.5° C.

2. *Turbidity and Fouts*.—By allowing 25 c.c. of the oil to stand between 60° and 80° F. for two weeks in a graduated glass tube, one centimeter in diameter, reporting amount of sediment found in c.c.'s or in fractions thereof.

3. *Breaking Test*.—By heating a portion of the oil, say 15 c.c., in a $\frac{5}{8}$ x 6-in. test tube over an open flame to 300° C., the temperature to be determined by a thermometer suspended in the oil. The rise in temperature should not exceed 50° per minute. Report whether oil breaks or not.

4. *Moisture and Volatile Matter*.—(a) Loss sustained by 2 grams of the oil in a 4-oz. Erlenmeyer flask at 105° C. in a current of dry hydrogen or pure carbonic acid gas (free from sulphur) to constant weight. (b) Loss sustained by 5 grams of oil in a 2½-in. uncovered Petri dish at 100° C. in an ordinary steam-jacketed oven for two hours.

5. *Ash*.—By burning 10 grams to complete combustion and to a light gray residue in a porcelain crucible or dish at a dull red heat.

6. *Drying Test on Glass*.—Follow Archbutt's method ("A piece of polished plate glass seven centimeters square by four millimeters thick is cleaned and counterpoised on the balance; it is then heated for an hour at 200° C. in an air bath to dry it thoroughly. It is taken out and laid on a non-conductor, allowed to cool for three or four minutes and the hot glass thinly painted with the oil to be tested, using a camel hair brush. When the glass is cold it is weighed and sufficient oil added to make it up to 0.1 gram." Gill's description) in the preparation of the glass slips and their coating with oil, placing in an atmosphere moderately dry, say a closet dessicator dried with sulphuric acid in which the moisture is not more than 25 per cent. saturation (temperature 60° to 80° F.). Report time required for the oil to become dry to the touch—i. e., no oil sticks to or is removed by the finger when touched lightly.

7.* *Oxygen Absorption, Using Lead Monoxide*.—Follow the method described in Department of Agriculture, Bureau of Chemistry, Bulletin 109, page 7. The sample of lead monoxide for use in this test will be furnished by the Committee. Report maximum gain and time to reach it.

8. *Acid Number*.—Expressed in milligrams of KOH per gram of oil. Follow the method described in Department of Agriculture, Bureau of Chemistry, Bulletin 107, revised page 142.

9. *Saponification Number*.—Expressed as with acid number and stating length of time test is run. Blanks should also be run to cover effect of alkali in glass. Follow the method given in the above referred to Bulletin 107, pages 137-138.

10. *Unsaponifiable Matter*.—Follow Boemer's method taken from Ubbelohde's *Handbuch der Ole u. Fette*, p. 261-2. "To 100 grams of oil in a 1000 to 1500-c.c. Erlenmeyer flask add 60 c.c. of an aqueous solution of potassium hydroxide (200 grams KOH dissolved in water and made

* Request was made later on that tests be made using ten (10) grams of litharge as well as five (5).

up to 300 c.c.) and 140 c.c. of 95 per cent. alcohol. Connect with a reflux condenser and heat on the water bath, shaking at first until the liquid becomes clear. Then heat for one hour with occasional shaking. Transfer while yet warm to a 2000-c.c. separatory funnel to which some water has been added, wash out the Erlenmeyer with water using in all 600 c.c. Cool, add 800 c.c. of ether and shake vigorously one minute. In a few minutes the ether solution separates perfectly clear. Draw off the soap and filter the ether (to remove last traces of soap) into a large Erlenmeyer and distill off the ether, adding if necessary one or two pieces of pumice stone. Shake the soap solution three times with 400 c.c. of ether, which add to the first ether extract. To the residue left after distilling the ether add 3 c.c. of the above KOH solution, and 7 c.c. of the 95 per cent. alcohol, and heat under reflux condenser for ten minutes on the water bath. Transfer to a small separatory funnel, using 20 to 30 c.c. of water, and after cooling shake out with two portions of 100 c.c. of ether; wash the ether three times with 10 c.c. of water. After drawing off the last of the water, filter the ethereal solution so as to remove the last drops of water, distill off the ether, dry residue in water oven and weigh."

After determination of unsaponifiable matter, convert it to acetate and determine the melting point of the acetate as directed by Lewkowitsch, page 372, Third Edition.

11. *Liebermann-Storch Test*.—Qualitative. Follow the method described in Bulletin 109 of Department of Agriculture, Bureau of Chemistry, referred to above.

12. *Refractive Index*.—Using Abbé Refractometer at 25° C.

13. *Acetyl Value*.—Follow Benedikt-Lewkowitsch method. See Department of Agriculture, Bureau of Chemistry, Bulletin 107, revised page 142.

14. *Hexabromide Test*.—On oil, determining the melting point of the bromide compounds. Method to be followed: The determination should be made in glass-stoppered weighing bottles, about 6 ins. high and 1 in. in diameter, with flat bottom, and weighing about 30 grams each. These bottles should be carefully dried and weighed. Weigh into one of these bottles 0.3 gram of oil to be tested; add 25 c.c. of absolute ether; cool to near 0° Centigrade; add bromine, drop by drop, until a considerable excess is shown by the color of the solution. Stir constantly during this addition, and add bromine very slowly to avoid heating. Place tube in ice water for thirty minutes; then in centrifuge, whirling for two minutes at speed of 1,200 revolutions per minute. This throws the brominated oil to the bottom of the tube, from which the supernatant liquid can be easily and quickly decanted. Add 10 c.c. of cold ether; stir precipitate with glass rod; allow to stand in ice water until thoroughly cold. Whirl in centrifuge again, and decant supernatant liquor. Another washing in the same manner will remove the excess of bromine and oil. Allow the tube and residue to stand for a short time, until the ether has evaporated; dry in water bath for thirty minutes, and weigh (Tolman's method).

Where it is impracticable to follow the above described method, follow such other method as may appeal to the analyst, describing it in the report.

15. *Iodine Number*.—Follow the Hanus method as described in Department of Agriculture, Bureau of Chemistry, Bulletin 107, revised page 136.

IMPORTANCE OF THIS WORK.

The importance of this work is clearly seen when it is considered that most of our State legislatures have passed bills prohibiting the adulteration of linseed oil. Linseed oil is largely purchased on specifications, which specifications would be very much improved if the Constants of Linseed Oil were used, provided these Constants were accurately determined. The purpose of this examination is to furnish data on which to base such specifications and provide such standards of purity.

Report these samples by numbers: No. 1, National Lead Company's; No. 2, Hirst & Begley's; No. 3, American Linseed Company's; No. 4, Archer-Daniels Company's.

Each sampling committee also took, as was directed, a sample of the seed used in the production of the linseed oil sampled. These samples were labeled as follows:

AMERICAN SOCIETY FOR TESTING MATERIALS

	Sample of Flaxseed	
Taken at	National Lead Co.'s Atlantic	Mill.
Remarks	Taken by automatic sampler as seed went through grinding rolls.	

Feb. 2, 1909.

The undersigned committee certify that the sample described above and contained within has been taken under their supervision and according to directions of the above Society's sub-committee.

PARKER C. McILHINEY, *Chairman*.
C. N. FORREST.

AMERICAN SOCIETY FOR TESTING MATERIALS

	Sample of Linseed	
Taken at	Hirst & Begley	Mill.
Remarks	Same as average seed from which oil was extracted.	

Feb. 3, 1909.

The undersigned committee certify that the sample described above and contained within has been taken under their supervision and according to directions of the above Society's sub-committee.

EDWARD GUDEMAN, *Chairman*.
W. R. SMITH,
A. L. WINTON,

AMERICAN SOCIETY FOR TESTING MATERIALS.

Sample of
Linseed

Taken at	American Linseed Co., S. Chicago, Ill.,	Mill.
Remarks	Same as average from which oil was extracted.	

Feb. 6, 1909.

The undersigned committee certify that the sample described above and contained within has been taken under their supervision and according to directions of the above Society's sub-committee.

EDWARD GUDEMAN, *Chairman*.
A. L. WINTON,
W. R. SMITH.

AMERICAN SOCIETY FOR TESTING MATERIALS.

Sample of
Flaxseed

Taken at	Archer-Daniels Linseed Co., Minneapolis,	Mill.
Remarks	A mixed composite sample corresponding to the oil sampled on same day.	

Feb. 13, 1909.

The undersigned committee certify that the sample described above and contained within has been taken under their supervision and according to directions of the above Society's sub-committee.

A. S. MITCHELL, *Chairman*.
RODNEY M. WEST,
F. G. SMITH.

The samples of seed were sent to F. W. Eva, Chief Inspector of Grain for the State of Minnesota in St. Paul, Minnesota, for examination. His report is as follows:

MR. GUSTAVE W. THOMPSON, *Chairman*,
Brooklyn, N. Y.

Dear Sir:

This will acknowledge receipt of your favor of the 20 inst., with check for \$3.00 in payment of inspection on four samples of flaxseed, which also reached me this morning.

I have personally tested these samples and enclose herewith certificates covering same, viz: Samples Nos. 1, 2, and 3, Grade No. 1 flaxseed, with $1\frac{3}{4}$, $1\frac{1}{2}$ and $1\frac{1}{2}$ per cent. dockage, respectively, and sample No. 4,

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Grade No. 1, Northwestern, with 4 per cent. dockage. The dockage on the last sample is largely composed of mustard seed and cracked flaxseed. In fact all of the samples show quite a percentage of cracked flaxseed.

I am returning the samples by express to-day.

Yours truly,

(Signed)

F. W. EVA,
Chief Inspector.

STATE OF MINNESOTA					
OFFICE OF					
Chief Inspector of Grain					
ST. PAUL DISTRICT					
St. Paul, Minn., May 24 - 1909					
THIS CERTIFIES, That there was inspected, under the supervision of the State Grain Inspection Department:					
(MINNESOTA GRADES)					
CAR NUMBER	CAR INITIAL	DATE INSPECTED	CONTENTS	GRADE	REMARKS
Sample No 1		24/09	Flax	No. 1 - 1 3/4 %	

Any Claim for improved inspection should be filed in this office before the time for appeal expires, or the claim will be considered as having been left this department.

F. W. EVA,
CHIEF INSPECTOR
ST. PAUL, MINN.

F. W. Eva
CHIEF INSPECTOR

STATE OF MINNESOTA					
OFFICE OF					
Chief Inspector of Grain					
ST. PAUL DISTRICT					
St. Paul, Minn., May 24 - 1909					
THIS CERTIFIES, That there was inspected, under the supervision of the State Grain Inspection Department:					
(MINNESOTA GRADES)					
CAR NUMBER	CAR INITIAL	DATE INSPECTED	CONTENTS	GRADE	REMARKS
Sample No 2		24/09	Flax	No. 1 - 1 1/2 %	

Any Claim for improved inspection should be filed in this office before the time for appeal expires, or the claim will be considered as having been left this department.

F. W. EVA,
CHIEF INSPECTOR
ST. PAUL, MINN.

F. W. Eva
CHIEF INSPECTOR

STATE OF MINNESOTA					
OFFICE OF					
 Chief Inspector of Grain ST. PAUL DISTRICT St. Paul, Minn., <u>May 24</u> 190<u>7</u> THIS CERTIFIES, That there was inspected, under the supervision of the State Grain Inspection Department:					
(MINNESOTA GRADES)					
CAR NUMBER	CAR INITIAL	DATE INSPECTED	CONTENTS	GRADE	REMARKS
Sample No 3		5/24/09	Flax	No 1 - 1 1/2 %	
F. W. EVA, CHIEF INSPECTOR ST. PAUL, MINN.			<u>F. W. Eva</u> <u>Per J.</u> CHIEF INSPECTOR		

Any Claim for improper inspection should be filed in this office at once, and before the grain is reloaded or has left this department.

STATE OF MINNESOTA					
OFFICE OF					
 Chief Inspector of Grain ST. PAUL DISTRICT St. Paul, Minn., <u>May 24</u> 190<u>7</u> THIS CERTIFIES, That there was inspected, under the supervision of the State Grain Inspection Department:					
(MINNESOTA GRADES)					
CAR NUMBER	CAR INITIAL	DATE INSPECTED	CONTENTS	GRADE	REMARKS
Sample No 4		5/24/09	Flax	No 1. NW - 4%	
F. W. EVA, CHIEF INSPECTOR ST. PAUL, MINN.			<u>F. W. Eva</u> <u>Per J.</u> CHIEF INSPECTOR		

Any Claim for improper inspection should be filed in this office at once, and before the grain is reloaded or has left this department.

The reports of the results, so far received, are given on the following pages in tabulated form, with the analyst's number in the first column. The individual reports in full appear in Appendix I.

TABULATED RESULTS OBTAINED BY TESTING LINSEED OIL SAMPLES.

1a. *Specific Gravity at 15.5° C.*

Analyst. Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
1 0.9346	0.9338	0.9338	0.9346
3 0.9342	0.9327	0.9326	0.9341
6 0.9344	0.9313	0.9319	0.9330
7 0.9349	0.9333	0.9336	0.9351
8 0.9344	0.9330	0.9331	0.9344
9 0.9342	0.9331	0.9329	0.9341
12 0.9343	0.9325	0.9336	0.9343
15 0.9341	0.9328	0.9330	0.9339
17 0.9356	0.9349	0.9346	0.9352
22 0.9342	0.9329	0.9330	0.9339
24 0.9352	0.9334	0.9334	0.9344
25 0.9338	0.9328	0.9324	0.9342
26 0.9352	0.9335	0.9336	0.9352
29 0.9355	0.9340	0.9344	0.9361
31 0.9348	0.9325	0.9330	0.9340

1b. *Specific Gravity at 25° C.*

1 0.9298	0.9285	0.9286	0.9294
3 0.9298	0.9283	0.9283	0.9296
6 0.9284	0.9268	0.9271	0.9280
7 0.9291	0.9283	0.9283	0.9294
8 0.9298	0.9286	0.9286	0.9299
9 0.9297	0.9280	0.9283	0.9297
12 0.9303	0.9287	0.9284	0.9291
15 0.9300	0.9278	0.9287	0.9295
17 0.9287	0.9264	0.9267	0.9291
22 0.9289	0.9274	0.9277	0.9289
24 0.9301	0.9284	0.9288	0.9298
25 0.9298	0.9286	0.9287	0.9302
26 0.9300	0.9286	0.9287	0.9300
29 0.9303	0.9290	0.9296	0.9310
31 0.9296	0.9281	0.9285	0.9294

2. *Turbidity and Fouts in Cubic Centimeters.*

Analyst.	Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
1	0.75	0.10	0.65	0.65
3	0.80	0.50	0.50	0.50
6	0.70	0.50	0.50	0.62
7	0.85	0.40	0.40	0.60
8	1.00	0.50	0.50	0.90
9	0.70	0.25	0.25	0.70
12	0.60	0.65	0.75	0.50
15	0.90	0.40	0.30	0.80
17	0.60	0.20	0.25	0.55
22	0.90	0.30	0.40	0.80
25	0.71	0.14	0.21	0.64
26	0.80	0.25	0.30	0.55
30	0.80	0.40	0.30	0.70
31	0.50	0.20	0.30	0.50

3. *Breaking Test.*

1	yes	no	no	yes
3	"	"	"	"
6	"	"	"	"
7	"	"	"	no
8	"	"	yes	yes
9	"	"	no	"
12	no	"	"	"
15	yes	"	"	"
17	no	"	"	"
22	yes	"	"	"
25	"	"	"	"
26	"	"	"	"
29	"	"	"	"
30	"	"	"	"
31	"	"	"	"

4a. *Percentage of Moisture and Volatile Matter in Current of (Column 6).*

1	0.022	0.071	0.200	0.046	H ₂
3	0.100	0.120	0.330	0.090	CO ₂
7	0.119	0.200	0.235	0.120	
15	0.000	0.000	0.120	0.000	
17	0.756	0.534	0.0488	0.491	
22	0.04	0.02	0.06	none	H ₂
25	0.030 gain	0.50	0.130	0.020	CO ₂
31	0.10 " "	0.13 gain	0.08	0.08 gain	H ₂

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4b. *Percentage of Moisture and Volatile Matter in Oven at 100° C.*

Analyst.	Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
1.....	0.073	0.060	0.219	0.065
3.....	0.090	0.090	0.260	0.08
7.....	0.009	slight gain	0.148	slight gain
8.....	0.080	0.090	0.230	0.060
9.....	0.052	0.041	0.212	0.056
12.....	none	0.040 gain	0.170	none
17.....	0.097	0.037	0.166	0.118
22.....	0.004	none	0.160	0.03
25.....	0.016	0.013 gain	0.128	0.052
26.....	0.054	0.231	0.217	0.034
29.....	0.032	0.023	0.209	0.045
30.....	0.030 gain	0.100 gain	0.090	0.030
31.....	0.055 "	0.000	0.185	0.010 gain

5. *Percentage of Ash.*

1.....	0.116	0.017	0.039	0.096
3.....	0.200	trace	0.030	0.190
6.....	0.135	0.033	0.060	0.170
7.....	0.135	0.025	0.030	0.160
8.....	0.140	0.030	0.040	0.160
9.....	0.140	0.025	0.034	0.149
12.....	0.135	0.035	0.050	0.145
15.....	0.120	0.010	0.030	0.160
17.....	0.125	0.030	0.030	0.131 on filtered
22.....	0.140	0.025	0.040	0.160 [solution.
25.....	0.139	0.028	0.038	0.154
26.....	0.135	0.030	0.040	0.143
29.....	0.134	0.027	0.033	0.163
30.....	0.140	0.030	0.042	0.162
31.....	0.156	0.047	0.048	0.159

6. *Drying Test on Glass in Hours.*

1.....	134	120	120	134
3.....	180-192	108-144	96-108	180
7.....	84	72	84	72
8.....	264	288-312	288	240
9.....	80	67-71	87-115	84-93
22.....	72	75	72	72
25.....	30	30	30	30 drying not
26.....	140	120	100	160 [complete.
30.....	108	116	158	170
31.....	168	120	144	168

7a. Oxygen Absorption—5 Grams PbO.

Analyst.	Sample No. 1.		Sample No. 2.		Sample No. 3.		Sample No. 4.	
	Per cent.	Time, hours.	Per cent.	Time, hours.	Per cent.	Time, hours.	Per cent.	Time, hours.
3...	15.5	120	11.8	120	9.6	120	11.0	120
4...	1.5	168	9.5	168	10.8	168	9.1	168
6...	16.6	144	12.7	144	13.5	144	13.6	144
7...	15.10	93	13.9	72	12.50	48	14.2	88
8...	7.47	96	7.87	96	8.18	96	9.37	96
9...	11.03	118	8.92	93	8.70	95	9.40	115
17...	6.48	48	6.48	48	6.41	48	7.60	48
22...	13.10	...	10.69	...	10.59	...	10.76	...
25...	6.23	48	8.11	48	9.01	48	8.39	48
26...	10.75	120	4.97	120	11.24	120	9.76	120
30...	10.19	100	10.41	100	10.53	100	10.57	100
31...	6.28	540	5.11	540	6.74	540	6.86	540

7b. Oxygen Absorption—10 Grams PbO.

1...	19.54	120	18.97	120	17.79	120	18.05	120
3...	15.5	120	13.2	120	15.3	120	15.3	120
4...	19.00	168	13.30	168	15.10	168	14.40	168
6...	14.6	144	14.4	96	14.6	96	14.5	96
9...	14.73	118	13.58	93	14.0	95	14.95	93
15...	9.08	48	6.77	48	9.30	48	8.30	48
22...	15.16	...	14.09	...	13.96	...	14.44	...
25...	13.79	120	13.40	240	13.29	120	13.68	120
26...	14.03	65	13.04	65	13.20	65	14.08	65
31...	15.04	277	11.53	540	14.64	277	15.17	277

8. Acid Number.

1.....	0.99	2.83	1.67	1.46
3.....	1.00	3.40	1.80	1.50
4.....	0.90	3.30	1.10	1.40
6.....	1.20	3.65	2.20	1.75
7.....	1.30	3.10	1.90	1.70
8.....	1.12	3.42	1.76	1.34
9.....	1.18	3.57	1.98	1.71
12.....	1.26	3.36	1.89	1.54
15.....	1.14	3.50	1.93	1.57
17.....	1.12	3.77	2.17	1.69
20.....	1.00	3.32	1.67	1.31
22.....	1.20	3.73	2.07	1.66

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8. Acid Number (Continued).

Analyst.	Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
24.....	1.37	3.64	2.09	1.62
25.....	1.15	3.75	2.06	1.70
26.....	1.20	3.57	1.95	1.71
31.....	1.21	3.49	1.91	1.57

9. Saponification Number.

1.....	190.1	191.2	190.7	191.0
3.....	190.2	190.6	190.2	190.1
6.....	188.6	189.6	189.2	189.7
7.....	190.7	191.4	189.7	190.0
8.....	190.1	189.1	189.2	190.5
9.....	192.2	191.4	190.8	190.4
12.....	190.8	191.2	191.2	190.0
15.....	189.0	188.6	189.4	189.2
17.....	189.98	190.6	189.6	188.7
20.....	191.58	190.4	190.69	190.86
22.....	191.31	191.23	191.1	190.9
24.....	191.7	191.4	191.1	191.0
25.....	190.7	190.3	189.7	190.5
26.....	193.4	193.1	192.7	194.4
31.....	184.5	183.7	183.7	185.5

10a. Percentage of Unsaponifiable Matter.

1.....	0.85	0.94	0.96	0.86
3.....	1.08	1.03	1.02	1.08
7.....	1.02	0.98	0.96	1.05
9.....	1.15	0.83	1.41	1.71
17.....	0.99	0.98	1.05	0.99
22.....	0.97	1.03	0.98	1.12
25.....	0.90	0.68	1.00	0.84 using petroleum ether
26.....	0.94	0.92	0.94	0.94

10b. Unsaponifiable Matter—Melting Point of Acetate in Degrees Centigrade.

3.....	126	126	128	127
9.....	125.5	120	126	121
17.....	128-130	128-130	128-130	128-103
26.....	129	105.5	104	103

11. *Liebermann-Storch Test—Colors.*

Analyst.	Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
1	Green	Green	Slight green	Slight green
3	Pale green	Pale green	Pale green	Pale green
6	Negative	Negative	Negative	Negative
7	"	"	"	"
8	"	"	"	"
9	Dark brown	Dark brown	Blackish brown	Blackish brown
12	Negative	Negative	Negative	Negative
15	"	"	"	"
17	"	"	"	"
22	"	"	"	"
25	"	"	"	"
26	"	"	"	"
30	"	"	"	"

12. *Refractive Index at 25° C.*

1	1.4799	1.4790	1.4793	1.4793
3	1.4805	1.4793	1.4795	1.4798
4	1.4805	1.4803	1.4802	1.4801
6	1.4805	1.4800	1.4800	1.4800
7	1.4794	1.4794	1.4798	1.4800
8	1.4802	1.4798	1.4802	1.4801
9	1.4800	1.4796	1.4799	1.4799
15	1.4796	1.4792	1.4790	1.4783
17	1.4798	1.4793	1.4796	1.4798
22	1.4797	1.4795	1.4795	1.4795
24	1.4800	1.4794	1.4795	1.4797
25	1.4780	1.4772	1.4775	1.4775
26	1.4799	1.4795	1.4800	1.4800

13. *Acetyl Value.*

1	26.4	24.4	27.1	21.6
3	4.1	4.2	4.1	5.7
7	11.7	9.9	7.8	7.9
9	29.95	29.08	29.13	29.11
17	27.05	12.9	21.7	19.8
24	14.8	14.8	12.0	12.7
25	5.42	6.20	6.30	4.78
	4.63	5.40	4.41	5.43
26	21.4	27.8	25.0	30.5

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14a. Hexabromide Test.

Analyst.	Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
1.....	30.3	30.87	29.55	19.84
	30.6	28.91		
	25.3			
3.....	44.0	44.5	39.3	41.2
4.....	26.20	19.4	11.8	14.2
	24.9	19.1	12.0	14.2
7.....	41.1	38.4	39.0	37.9
9.....	46.3	39.3	42.3	35.6
	27.7	21.6	27.1	22.9
	34.7	24.1	34.6	32.6
	48.1	44.1	43.9	46.0
	26.5	20.0	25.6	26.5
	34.6	29.9	39.1	35.0
15.....	42.9	42.9	44.8	39.0
17.....	56.6	49.3	48.1	48.2
22.....	40.9	39.7	40.5	40.0
25.....	41.1	36.7	38.6	43.0
	41.0	41.1	39.3	43.4
		48.8		

14b. Hexabromide Test—Melting Point of Hexabromide in Degrees Centigrade.

3.....	150	151	149	150
7.....	142	141.5	142	143
15.....	132	135	127	135
17.....	148-150	148-150	148-150	148-150

15. Iodine Number—Hanus Method.

1.....	187.5	184.3	186.9	185.5
3.....	186.8	183.2	186.8	185.0
4.....	184.2	182.9	182.5	184.1
6.....	186.8	183.7	185.7	187.0
7.....	190.0	186.9	191.2	188.6
8.....	189.3	186.0	188.4	186.1
9.....	185.8	183.3	186.5	185.1
12.....	182.3	183.3	184.7	182.6
15.....	180.8	177.2	179.2	177.5
17.....	192.7	184.2	186.3	188.7
22.....	189.9	186.0	189.5	187.6
24.....	187.0	185.7	181.9	185.8
25.....	184.3	183.4	185.5	183.3
26.....	188	186	188	189

The foregoing tabulation shows the following results as far as it has been considered wise to average them:

Sample No.	1.	2.	3.	4.
1a. Sp. gr. at 15.5° C.....	0.9347	0.9331	0.9331	0.9344
1b. " " " 25° ".....	0.9298	0.9284	0.9285	0.9295
2. Turbidity and foots, in c. c.	0.76	0.35	0.40	0.65
4. Moisture and volatile matter				
a	0.056	0.088	0.150	0.025
b	0.047	0.058	0.184	0.052
5. Ash.....	0.140	0.026	0.039	0.154
8. Acid number	1.15	3.50	1.94	1.58
9. Saponification number ..	190.6	190.1	190.1	190.2
10a. Unsaponifiable matter ...	0.99	0.96	0.99	0.98
12. Refractive index	1.4800	1.4794	1.4797	1.4797
15. Iodine number	187.9	184.5	186.1	186.0

In the main, the specifications for analysis, etc., submitted by the Committee, have proven satisfactory.

We would recommend that, provisionally, the methods given relating to specific gravity, acid number, saponification number, unsaponifiable matter, refractive index, and iodine number, be considered standard, and that a raw linseed oil shall be considered pure when it tests between the following:

	Maximum.	Minimum.
Specific gravity at 15.5° C.....	0.936	0.932
" " " 25° C.....	0.931	0.9270
Acid number	6.00	.....
Saponification number	192	189
Unsaponifiable matter, per cent.....	1.50	.....
Refractive index at 25° C.....	1.4805	1.4790
Hanus iodine number	190	178

These tests and specifications are advised simply for consideration during the coming year. They should be subjected to further rigid examination by your Committee and be made to run the gauntlet of the most severe criticism before their formal adoption.

While the tests for turbidity, moisture and volatile matter, ash, and the Liebermann-Storch test, show interesting results, we do not feel that we are warranted at the present time in offering them as provisionally standard. Further work will have to be done on these tests in order that they may be brought to a position of real value.

Much work must still be done to develop suitable tests for the

"drying coefficient" of linseed, if we may coin that expression. The "drying test on glass" gave such varied results that it would appear to be worthless as specified by your Committee. Some better method should be found to determine the drying rate (or "coefficient") of linseed oil.

The oxygen absorption test, using litharge as the agent, does not give results as satisfactory as are desired. Your Committee should do more work in reference to this test. The acetyl value and hexabromide tests also deserve special consideration, with the hope that new and better methods may be devised.

As your Committee has in reserve other portions of these samples of oil, carefully sealed, it is in a position to send out further samples without great difficulty or delay, so that the work suggested above can be carried out with promptitude.

Many other lines of work suggest themselves to your Committee, of which the following are the more important:

1. Development of other tests, including flash point, etc.
2. Examination of linseed oil produced from new and old seed, to discover what difference ageing of seed may have on oil.
3. Examination of oil from damaged and off-grade seed.
4. Examination of boiled oil.

Letters of regret have been received from the following analysts, explaining their failure to report.

Unable to make the analyses owing to stress of other duties:

11. A. J. Patten, Lansing, Mich.
13. J. E. Greaves, Logan, Utah.
14. E. F. Ladd, Fargo, North Dakota.
21. Paul Schweitzer, University of Missouri, Columbia, Mo.
27. Otto Eisenschimml, American Linseed Company, South Chicago, Ill.

Various reasons:

5. S. S. Voorhees, Engineer of Tests, Department of the Interior, U. S. Geological Survey, Washington, D. C.
The samples were lost in the fire.
10. H. H. Knisely, 310 Worcester Building, Portland, Oregon.
Did not receive the samples.
16. J. C. Dickerman, Madison, Wis.
Has not yet completed the work.
19. J. S. Jones, Moscow, Idaho.
Could not report on time.

It is hoped that their reports, coming in later, will help the work of your Committee during the coming year.

The thanks of the Society should be especially tendered to the National Lead Co., the Hirst and Begley Co., the American Linseed Co., and the Archer-Daniels Co., for the samples of linseed oil which they contributed, and for their general assistance in the work of the Committee; also to the members of the sampling committees, and to the analysts who have given so much of their time to the testing of the samples of oil.

Respectfully submitted,

G. W. THOMPSON,
Chairman, Sub-Committee on Linseed Oil.

The final work of the Committee has been undertaken in cooperation with Committee U on Corrosion of Iron and Steel. The full report of this Joint Committee is presented as Appendix II to this report.

In continuing the work of the Committee for the ensuing year, it is felt that a study of the underlying cause of the action of pigments on corrosion will be of much value. The field is a broad one and will require much careful investigation.

It is also the desire of the Committee to continue its study of the physical character of detached films and the relation of the size of pigment particles to strength and permeability.

It is further hoped that opportunity will be afforded the Committee to conduct additional service tests with white paints on wooden surfaces. The magnitude and the importance of the general class of house paints is so vital to the building interests of the entire country, that the report of this Committee must be based on very positive data.

Respectfully submitted on behalf of the Committee,

S. S. VOORHEES,
Chairman.

J. F. WALKER,
Secretary.

APPENDIX I.

COMPLETE REPORTS OF ANALYSTS.

REPORT OF G. W. THOMPSON.

Laboratory of the National Lead Company.

I submit, herewith, my report on the examination of the four samples of pure linseed oil sent by you. The analyses were performed by E. J. Sheppard, of this laboratory, under my supervision.

In all this work the 1909 atomic weights were used. Wherever the method employed differed from that prescribed in the circular, the modified method is given.

1a. SPECIFIC GRAVITY AT 15.5° C.

A calibrated 50-c. c. pycnometer was used for all specific gravity determinations.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
0.9346		0.9338	0.9346
0.9346	0.9338	0.9338	0.9345
0.9345	0.9338	0.9337	0.9346
0.9346	0.9338	0.9338	0.9346

1b. SPECIFIC GRAVITY AT 25° C.

	0.9285	0.9286	
0.9298	0.9285	0.9284	0.9294
0.9299	0.9284	0.9286	0.9294
0.9298	0.9285	0.9286	0.9294

2. TURBIDITY AND FOOTS IN CUBIC CENTIMETERS.

Ordinary glass tubing was sealed at one end, and 25 c. c. of the oil were added. After standing two weeks, the height of the column of foots was marked on the tube, the oil poured out, and the tubes cleaned. Water was run in from a burette and the reading obtained from the burette.

0.75	0.10	0.65	0.65
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3. BREAKING TEST.

Breaks at 260° C. Does not break. Does not break. Breaks at 265° C.

4. PERCENTAGE OF MOISTURE AND VOLATILE MATTER.

(a) The determination was made in a stream of dry hydrogen; the oil was weighed after cooling 30 minutes in a closet dessicator.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
0.020		0.234	0.050
0.026	0.073	0.170	0.038
0.020	0.069	0.196	0.049
0.022	0.071	0.200	0.046

(b) An ordinary steam-jacketed oven was used.

0.073	0.060	0.219	0.065
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5. PERCENTAGE OF ASH.

0.1194	0.0169	0.0426	0.096
0.114	0.0180	0.0386	0.084
0.115	0.0170	0.0360	0.108
0.116	0.0170	0.0390	0.096

6. DRYING TEST ON GLASS IN HOURS.

134	120	120	134
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7. OXYGEN ABSORPTION, USING LEAD MONOXIDE.

Preliminary.—An effort was made prior to the examination of these samples to obtain the oxide in a fairly uniform state of division, by taking

TABLE I.

Number.	Litharge.		Oil.	Increase in per cent. in — hours.				
	Sample.	Weight, grams.		24.	48.	72.	96.	192.
1	A	5	Boiled	3.28	....	3.61	....	4.21
2	"	5	"	3.69	....	4.16	....	4.67
3	"	10	"	5.54	....	6.44	....	7.44
4	B	5	"	4.47	....	4.94	....	5.52
5	"	5	"	5.09	....	5.64	....	6.51
6	"	10	"	7.26	....	8.83	....	8.89
7	C	5	"	7.22	7.97	8.14	8.35	....
8	"	5	"	6.04	6.57	6.84	6.95	....
9	"	10	"	14.72	15.83	16.32	16.46	....
10	"	5	Raw	2.26	7.17	....	....	....
11	"	10	"	8.71	8.89	....	....	....

the portion of light colored litharge which passes through a 100-mesh screen and separating it into portions which do and do not pass through a No. 21 silk cloth.

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Litharge.—Sample A.—Portion of colormaker's litharge passing through a 100-mesh screen but not passing through No. 21 cloth.

B.—Portion of colormaker's litharge passing through 100-mesh screen and also through No. 21 cloth.

TABLE II.

Number.	Litharge.		Oil.	Increase in per cent. in — hours.			
	Sample.	Weight, grams.		24.	48.	72.	96.
1	D	5	Raw	1.35	none	8.40	12.16
2	"	10	"	0.32	0.69	2.00	9.62
3	E	5	"	5.47	9.00	9.33	9.55
4	"	10	"	8.70	15.71	16.12	16.26

C.—Special fine litharge similar to that sent out by Committee.

D.—Sample received from P. H. Walker.

E.—Committee E sample.

The oil used in all cases was about 0.5 gram accurately weighed.

TABLE III.—TEN GRAMS LITHARGE, SAMPLE E.

Number	Sample Oil, No.	Increase in per cent. in — hours.				
		24.	48.	72.	96.	120.
1	1	16.33	18.02	....	18.40	18.68
2	"	17.56	19.20	....	19.52	19.67
3	"	17.54	19.22	....	19.43	19.59
4	"	18.94	20.01	....	....	20.61
5	"	18.26	19.29	....	....	19.50
6	"	17.42	18.71	....	....	19.24
7	2	16.93	18.51	....	....	18.90
8	"	15.95	17.77	....	....	18.17
9	"	16.43	18.06	....	....	18.38
10	"	17.76	18.66	....	....	19.33
11	"	17.24	18.16	....	....	18.82
12	"	18.42	19.45	....	....	20.24
13	3	15.79	16.79	17.65	....	18.10
14	"	15.30	17.37	....	....	17.73
15	"	13.67	15.98	16.05	....	16.65
16	"	16.17	18.38	....	....	18.96
17	"	15.09	17.65	....	....	17.88
18	"	13.70	16.99	....	....	17.42
19	4	14.68	17.27	17.45	....	18.02
20	"	13.59	16.24	16.55	....	17.24
21	"	14.24	16.88	17.07	....	17.62
22	"	14.25	17.96	....	....	18.56
23	"	13.45	17.44	....	....	18.07
24	"	13.89	18.17	....	....	18.83

All samples of linseed oil were of known purity.

For all determinations 2½-in. glass dishes were used.

From Table I it will be seen that the difference in size of the oxide particles had little influence upon the absorption; also, that 5 grams of litharge was insufficient for a complete absorption of oxygen in a minimum time even with boiled oil.

The use of 10 grams of litharge naturally suggested itself, with the result as indicated in Table I—that the use of 10 grams of PbO is productive of a more complete oxygen absorption in a minimum time.

As shown in Table II, sample D as well as the 5-gram charge of E, gave results too low to be considered.

The figures obtained indicate that for a comparative test the same variety of litharge should be used and that the absorption equilibrium is more quickly established with 10 grams than as recommended in Bulletin 109 of the Department of Agriculture, Bureau of Chemistry.

Committee Samples.—Table III contains the result obtained on the litharge E and the committee samples of oil. After 120 hours none gained appreciably; the majority, however, lost slightly.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
19.54	18.97	17.79	18.05

No determinations have been omitted.

8. ACID NUMBER.

(Expressed in milligrams of KOH per gram of oil.)

0.994	2.832	1.67	1.46
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9. SAPONIFICATION NUMBER.

(Expressed as in 8.)

189.5	191.3	190.7	
190.5	191.2	190.7	190.9
190.2	191.05	190.8	191.1
190.1	191.2	190.7	191.0

10. PERCENTAGE OF UNSAPONIFIABLE MATTER.

The lubricant was entirely removed from all stoppers and cocks of the separatory funnels.

0.85	0.94	0.96	0.86
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11. LIEBERMANN-STORCH TEST.

Negative.	Negative.	Negative.	Negative.
Green.	Green.	Slight green.	Slight green.

ON PRESERVATIVE COATINGS FOR STRUCTURAL MATERIALS. 171

12. REFRACTIVE INDEX AT 25° C.

The refractometer was standardized on water at 25° C., using the constant temperature apparatus.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
1.4799	1.4790	1.4793	1.4793

13. ACETYL VALUE.

(Expressed in milligrams of KOH per gram of oil.)

Series (a).

The oil was boiled with acetic anhydride in an Erlenmeyer flask, using a funnel as condenser. An excess of 2 c. c. of standard acid was used to liberate the fatty acids. This solution was not heated but the acids allowed to separate gradually.

42.4	37.6	34.8	42.3
	39.8	45.2	34.6

Series (b).

The oil was filtered directly into a small, round-bottomed flask and an equal volume of acetic anhydride added. The mixture was boiled several hours with frequent shaking. A long tube acted as a condenser. The rest of the method was carried out as in Series (a).

26.4	24.4	27.1	21.6
26.6	21.5		

The water used for washing the fatty acids was first vigorously boiled to free it from carbon dioxide, special care being taken to make this operation complete.

14. HEXABROMIDE TEST, IN PER CENT.

30.3	30.87	29.55	19.84
30.6	28.91		
25.3			

15. IODINE NUMBER.

187.3	184.1	186.87	185.3
187.4	184.3	186.80	185.9
187.9	184.5	186.90	185.2
187.6	184.3	186.90	185.5

The standardization of the potassium bichromate gave a figure slightly higher than on re-sublimed iodine.

REPORT OF COMMITTEE E

REPORT OF P. H. WALKER.

Contracts Laboratory, U. S. Department of Agriculture.

(Chemical work done by Mr. E. W. Boughton.)

1a. SPECIFIC GRAVITY AT 15.5° C.

(Determined with pyknometer.)

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
0.9342	0.9327	0.9326	0.9341

1b. SPECIFIC GRAVITY AT 25° C.

0.9298	0.9283	0.9283	0.9296
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2. TURBIDITY AND FOOTS IN CUBIC CENTIMETERS.

0.8	0.5	0.5	0.5
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3. BREAKING TEST.

Breaks.	Does not break.	Does not break.	Breaks.
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4a. PERCENTAGE OF MOISTURE AND VOLATILE MATTER.

(To constant weight at 105° C. in CO₂.)

0.10	0.12	0.33	0.09
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4b. PERCENTAGE OF MOISTURE AND VOLATILE MATTER.

(2 hours in steam oven.)

0.09	0.09	0.26	0.08
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5. PERCENTAGE OF ASH.

0.20	Trace	0.03	0.19
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6. DRYING TEST ON GLASS IN DAYS.

(Temperature 20° to 25° C.)

7.5	4.5	4.5	7.5
8	4	6	7.5

7. OXYGEN ABSORPTION WITH PbO.*

(Set 1) Committee PbO—5 grams PbO and 0.5 gram oil.

Per cent.	Hours.	Per cent.	Hours.	Per cent.	Hours.	Per cent.	Hours.
0.02	24	4.70	24	0.30	24	0.20	24
0.8	48	6.5	48	3.5	48	1.5	48
1.5	72	7.1	72	4.9	72	3.9	72
3.1	96	8.0	96	6.5	96	8.1	96
7.4	120	8.1	120	7.9	120	11.0	120

* Sets 1 and 1a were run at the same time; sets 2 and 2a were also run simultaneously, but not at the same time as sets 1 and 1a.

7. OXYGEN ABSORPTION WITH PbO (CONTINUED).

(Set 1a) Committee PbO—10 grams PbO and 0.5 gram oil.

Sample No. 1.		Sample No. 2.		Sample No. 3.		Sample No. 4.	
Per cent.	Hours.	Per cent.	Hours.	Per cent.	Hours.	Per cent.	Hours.
0.4	24	10.6	24	1.8	24	0.8	24
2.2	48	11.2	48	10.4	48	10.2	48
4.9	72	12.0	72	13.1	72	14.0	72
10.9	96	12.8	96	15.2	96	15.1	96
15.5	120	13.2	120	15.3	120	15.3	120

(Set 2) Committee PbO—5 grams PbO and 0.5 gram oil.

3.0	24	6.1	24	2.9	24	1.0	24
5.0	48	7.5	48	6.8	48	4.0	48
12.9	72	8.4	72	8.7	72	7.6	72
15.3	120	11.8	120	9.6	120	8.6	120

(Set 2a) Bureau of Chemistry PbO—5 grams PbO and 0.5 gram oil

2.2	24	9.8	24	8.8	24	5.1	24
9.1	48	11.0	48	11.4	48	10.4	48
13.0	72	11.6	72	13.1	72	13.3	72
14.6	120	11.9	120	13.3	120	14.2	120

8. ACID NUMBER.

1.0	3.4	1.8	1.5
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9. SAPONIFICATION NUMBER.

190.2	190.6	190.2	190.1
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10a. UNSAPONIFIABLE MATTER.

1.08	1.03	1.02	1.08
Microscopic examination of phytosterol.	Examination by Mr. B. J. Howard.	Hexagonal plates characteristic of phytosterol.	No indication of cholesterol.

10b. UNSAPONIFIABLE MATTER.

(Melting point of phytosterol acetate in degrees Centigrade.)

126	126	128	127
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Second crystallization. Readings made to 1° C.
Corrected for stem correction.

11. LIEBERMANN-STORCH TEST.

Pale green.	Pale green.	Pale green.	Pale green.
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REPORT OF COMMITTEE E

12. REFRACTIVE INDEX AT 25° C.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
1.4805	1.4793	1.4795	1.4798

13. ACETYL VALUE.

4.1	4.2	4.1	5.7
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14a. HEXABROMIDE TEST.

(Bromine Precipitate.)

		44.1	
42.6	40.9	40.3	
46.5	39.9	47.2	43.9
43.0	37.3	46.6	38.5
44.0	30.3	44.5	41.2

14b. MELTING POINT OF BROMINE PRECIPITATE.

(Degrees Centigrade.)

150	151	149	150
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(Readings made to 1° C. Corrected for stem correction.)

BROMINE IN BROMINE PRECIPITATE (PER CENT.).

57.2	57.7	57.4	57.7
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15. IODINE NUMBER.

(Acetic acid 99.5 per cent.—Melting point method.)

186.8	183.2	186.8	185.0
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REPORT OF A. H. GILL.

Massachusetts Institute of Technology, Boston.

7. DRYING TEST ON LITHARGE.

(a) 5 grams PbO.

	Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
48 hours.	2.3	7.9	6.0	5.1
	1.2			
1 week.	1.5	9.5	10.8	9.1

(b) 10 grams PbO.

48 hours.	1.5	13.2	13.4	5.9
1 week.	14.4	13.3	15.1	14.4
	19.0			

8. ACID NUMBER.

0.9	3.3	1.1	1.4
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12. REFRACTIVE INDEX.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
1.4805	1.4803	1.4802	1.4801

14. HEXABROMIDES, PER CENT.

26.20	19.4	11.8	14.2
24.9	19.1	12.0	14.2

15. IODINE NUMBER.

184.2	182.9	182.5	184.1
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REPORT OF GLENN H. PICKARD.

Spencer Kellogg Company, Buffalo, N. Y.

1a. SPECIFIC GRAVITY AT 15.5° C.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
0.9344	0.9313	0.9319	0.9330

1b. SPECIFIC GRAVITY AT 25° C.

0.9284	0.9268	0.9271	0.9280
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2. TURBIDITY AND FOOTS.

In making the turbidity and foots test, we first chilled one portion of the sample to 16° F. Then we took another portion of the sample and heated it to 180° F., and took another one right out of the bottle just as we received it. These were then put in a rack, side by side, and the test continued as directed with the following results:

Chilled to 16° F.

Per cent.	per cent.	Per cent.	Per cent.
5.5	2.5	3.5	5.25

Normal.

2.75	2	2	2.5
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Heated to 180° F.

2.5	None	0.5	2
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You perhaps may have noticed in the writer's article, as published in the *Painter's Magazine*, that he stated that a good deal of material which is termed foots is in reality not that substance at all, but some other, the exact composition of which we can only surmise, which separates when the oil is chilled. The writer is inclined to the idea that it is the high melting point fats which crystallize under the conditions existing when the temperature is reduced. The result of this test would seem to be additional proof to this statement, because the chilled oil is in every case higher while the oils in which we should expect to find none of the mucilaginous or other matter which is normally called foots, show almost

none when that sample has been heated up to 180° F., and not allowed to chill again during the period in which the sediment is forming. And yet, from this same oil when it is chilled there is a precipitate which looks and acts very much like the material normally termed foots by the linseed oil consuming trade.

This is a bit of data which we thought might be of interest to you, and possibly of interest enough to bear incorporation in the report.

3. BREAKING TEST.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
Broke.	Did not break.	Did not break.	Broke.

5. PERCENTAGE OF ASH.

0.135	0.033	0.06	0.17
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7. OXYGEN ABSORPTION.

(a) 5 grams PbO.

Per cent.	Hours.	Per cent.	Hours.	Per cent.	Hours.	Per cent.	Hours.
16.6	144	12.7	—	13.5	—	13.6	—

(b) 10 grams PbO.

14.6	144	14.4	96	14.6	96	14.5	96
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These are all the results which we have been able to get, owing to lack of time, and in one instance to the fact that we did not have the proper dessicator to keep the relative humidity of the drying atmosphere the same at all times.

8. ACID NUMBER.

1.2	3.65	2.2	1.75
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9. SAPONIFICATION NUMBER.

188.6	189.6	189.2	189.7
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11. LIEBERMANN-STORCH TEST.

The Liebermann-Storch Test for rosin or rosin oil was negative in each instance.

12. REFRACTIVE INDEX AT 25° C.

1.4805	1.4800	1.4800	1.4800
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15. IODINE NUMBER.

186.8	183.7	185.7	187.0
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ON PRESERVATIVE COATINGS FOR STRUCTURAL MATERIALS. 177

REPORT OF H. M. LOOMIS.

Acting Chief, Food and Drug Inspection Laboratory,
Seattle, Wash.

1a. SPECIFIC GRAVITY AT 15.5° C.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
0.9342	0.9331	0.9329	0.9341

1b. SPECIFIC GRAVITY AT 25° C.

0.9297	0.9280	0.9283	0.9297
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2. TURBIDITY AND FOOTS IN CUBIC CENTIMETERS.

0.70	0.25	0.25	0.70
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3. BREAKING TEST.

Breaks at 250-270° C.	Does not break.	Does not break.	Breaks at 250-265° C.
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4b. PERCENTAGE OF MOISTURE AND VOLATILE MATTER.

0.052	0.041	0.212	0.056
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5. PERCENTAGE OF ASH.

0.14	0.025	0.034	0.149
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6. DRYING TEST ON GLASS IN HOURS.

(Made in laboratory near east window.)

80 (2 tests)	67 71	115 91 87	93 84
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7. OXYGEN ABSORPTION.

(a) 5 Grams Litharge.

Per cent.	Hours.	Per cent.	Hours.	Per cent.	Hours.	Per cent.	Hours.
3.32	48	5.30	48	4.32	48	6.49	48
5.77		8.05		7.41		7.85	
		6.73					

(maximum.)

11.03	118	9.92	93	8.70	95	10.06	93
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(b) 10 Grams Litharge.

12.8	48	10.74	48	10.21	48	10.95	48
		11.85		12.6			

(maximum.)

14.73	118	13.58	93	14.0	95	14.95	93
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REPORT OF COMMITTEE E

8. ACID NUMBER.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
1.18	3.57	1.98	1.71

9. SAPONIFICATION NUMBER.

(Run $\frac{1}{2}$ hour.)

192.2	191.4	190.8	190.4
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10a. PERCENTAGE OF UNSAPONIFIABLE MATTER.

1.15	0.83	1.41	1.71
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10b. MELTING POINT OF ACETATE FROM UNSAPONIFIABLE MATTER.

125.5	120	126	121
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11. LIEBERMANN-STORCH TEST.

Dark green, turning quickly to brownish- black.	Dark brown, turning darker and more opaque.	Blackish brown, turning darker.	Blackish brown, turning darker.
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12. REFRACTIVE INDEX AT 25° C.

1.4800	1.4796	1.4799	1.4799
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15. IODINE NUMBER.

(Standing $\frac{1}{2}$ hour.)

185.8	183.3	186.5	185.1
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ODOR AND TASTE.

Sample No. 1.

Appearance.—Orange yellow with slight flocculent white sediment.*Odor and Taste.*—Nutty.

Sample No. 2.

Appearance.—Orange yellow color, but little lighter than No. 1, with sediment as in No. 1.*Odor and Taste.*—Nutty.

Sample No. 3.

Appearance.—Same as No. 2.*Odor.*—Resembling mineral oil.*Taste.*—Slight, resembling mineral oil.

Sample No. 4.

Appearance.—Brownish yellow color. Slight sediment.*Odor.*—Nutty.*Taste.*—Nutty and slightly bitter.

NOTES.

Hexabromide Test.—Followed Tolman's method as given, except that Babcock cream bottles were used instead of weighing bottles. In working the hexabromide precipitate, stirring rods were not used; simply shaking flask and contents with the other served to detach the precipitate from the flask and insure thorough washing. The result on this test was very unsatisfactory, although great care was taken to carry out the test uniformly. Seven determinations were run on each oil and while the four results on each series were quite concordant, I obtained results varying from 20 to 58 per cent. Lack of time made it impossible for me to find the cause of this wide variation.

ADDITIONAL REPORT FROM H. M. LOOMIS.

Thinking it may be of interest to you to have my results on the acetyl value and hexabromide test, I am sending them herewith, and you may publish them or not as you see fit.

13. ACETYL VALUE.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
29.95	29.08	29.13	29.11

14. HEXABROMIDE TEST, IN PER CENT.

Bromine was added drop by drop from a burette, cooling in ice and water mixture between each addition.

46.3	39.3	42.3	35.6
27.7	21.6	27.1	22.9
34.7	34.1	34.6	32.6
48.1	44.1	43.9	46.0
26.5	20.0	25.6	26.5
34.6	29.9	39.1	35.0

REPORT OF S. R. MITCHELL.

New Mexico College of Agriculture and Mechanic Arts, New Mexico.

1a. SPECIFIC GRAVITY AT 15.5° C.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
0.9344	0.9325	0.9336	0.9343

1b. SPECIFIC GRAVITY AT 25° C.

0.9303	0.9287	0.9284	0.9291
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A 50-c. c. pyknometer was used.

2. TURBIDITY AND FOOTS IN CUBIC CENTIMETERS.

0.60	0.65	0.75	0.50
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A graduated test tube was used.

3. BREAKING TEST.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
No break.	No break.	No break.	Broke at 280°.

4b. MOISTURE AND VOLATILE MATTER.

Same.	0.002 gram gain.	0.0085 gram loss.	Same.
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The heating was done in a steam-jacketed oven at boiling point of water, which at this altitude is 97° C. Determinations were also made on filtered oil with the following results:

0.001 gram gain.	0.0025 gram gain.	0.006 gram loss.	0.0005 gram loss.
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5. PERCENTAGE OF ASH.

0.135	0.035	0.05	0.145
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The percentage of ash on No. 4 may be a little high. A muffle was used on all. Ash determinations were also made on the filtered oil of three samples with following results:

0.13	0.03	0.04
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8. ACID NUMBER.

1.26	3.36	1.89	1.54
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9. SAPONIFICATION NUMBER.

190.78	191.18	191.18	190.01
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The contents of the flasks were allowed to simmer (not boil) for 30 minutes. At first the boiling method was tried, but the contents boiled over and spoiled the results.

11. LIEBERMANN-STORCH TEST.

No rosin.	No rosin.	No rosin.	No rosin.
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15. IODINE NUMBER.

182.3	183.3	184.7	182.6
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REPORT OF F. S. KEDSIE.

Michigan Agricultural College, East Lansing, Mich.

The following is the work done on the four samples of linseed oil by Prof. H. S. Reed of this department. All of the tests were carefully made, but none in duplicate, and the report therefore represents the work of an experienced man in applying the tests as laid down.

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1a. SPECIFIC GRAVITY AT 15.5° C.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
0.935620	0.934866	0.934634	0.935188

1b. SPECIFIC GRAVITY AT 25° C.

0.928704	0.926424	0.926726	0.929130
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2. TURBIDITY AND FOOTS IN CUBIC CENTIMETERS.

0.6	0.2	0.25	0.55
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3. BREAKING TEST.

0	0	0	Broke.
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4b. PERCENTAGE OF MOISTURE AND VOLATILE MATTER.

(Drying in oven at 100° C.)

a.	0.756	0.534	0.0488	0.491
b.	0.09693	0.03714	0.1656	0.1175

5. PERCENTAGE OF ASH.

(On filtered sample.)

0.125	0.03	0.03	0.131
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6. DRYING TEST ON GLASS.

(Not satisfactory.)

7. OXYGEN ABSORPTION.

(Per cent. gain in 48 hours at 75° F. Glass dishes used.)

6.479	6.477	6.411	7.598
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8. ACID NUMBER.

1.12	3.77	2.17	1.69
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9. SAPONIFICATION NUMBER.

189.98	190.6	189.6	188.7
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10a. PERCENTAGE OF UNSAPONIFIABLE MATTER.

0.99	0.975	1.052	0.987
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10b. UNSAPONIFIABLE MATTER.

(Results obtained on 4 samples.)

Crystals of phytosterol plainly discernible. No evidence of cholesterol. Melting point of phytosterol acetate, 128–130° C.

11. LIEBERMANN-STORCH TEST.

0	0	0	0
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REPORT OF COMMITTEE E

12. REFRACTIVE INDEX.

(Using Zeiss Butyro-Refractometer.)

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
1.4798	1.4793	1.4796	1.4798

13. ACETYL VALUE.

(Milligrams of KOH required to saponify 1 gram acetylated oil.)

27.05 ?	12.9 ?	21.7 ?	19.8 ?
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14a. HEXABROMIDE TEST, PER CENT.

(According to Hehner and Mitchell.)

56.6	49.3	48.1	48.2
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14b. MELTING POINT OF BROMIDES.

All four samples melted between 148° and 150° C.

15. IODINE NUMBER.

192.7	184.2	186.3	188.7
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REPORT OF E. J. SHANLEY.

Food and Drug Inspection Laboratory, Chicago, Ill.

1a. SPECIFIC GRAVITY AT 15.5° C.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
0.9342	0.9329	0.9330	0.9339

1b. SPECIFIC GRAVITY AT 25° C.

0.9289	0.9274	0.9277	0.9289
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2. TURBIDITY AND FOOTS IN CUBIC CENTIMETERS.

0.9	0.3	0.4	0.8
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3. BREAKING TEST.

(300°.)

Breaks.	No break.	No break.	No break.
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4a. PERCENTAGE OF MOISTURE AND VOLATILE MATTER IN HYDROGEN.

0.04	0.02	0.06	None.
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4b. PERCENTAGE OF MOISTURE AND VOLATILE MATTER IN AIR.

None.	None.	0.19	0.03
0.004	Gained.	0.13	None.

ON PRESERVATIVE COATINGS FOR STRUCTURAL MATERIALS. 183

5. PERCENTAGE OF ASH			
Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
0.14	0.03	0.03	0.16
0.14	0.02	0.05	0.16

6. DRYING TEST ON GLASS IN HOURS.

7 ²	75	7 ²	7 ²
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7. OXYGEN ABSORPTION, USING LEAD MONOXIDE.

(a) 5 grams PbO.

Per cent.	Per cent.	Per cent.	Per cent.
13.10	10.69	10.59	10.76

(b) 10 grams PbO.

15.16	14.09	13.96	14.44
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8. ACID NUMBER.

1.2	3.73	2.07	1.66
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9. SAPONIFICATION NUMBER.

191.31	191.23	191.10	190.90
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10a. UNSAPONIFIABLE MATTER.

0.97	1.03	0.98	1.12
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11. LIEBERMANN-STORCH TEST.

Negative.	Negative.	Negative.	Negative.
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12. REFRACTIVE INDEX.

1.4797	1.4795	1.4795	1.4795
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14a. HEXABROMIDE TEST.

40.89	39.67	40.49	40.03
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15. IODINE NUMBER.

189.82	186.09	189.19	187.48
190.05	186.03	189.85	187.79

In the drying test on glass, the slides were left standing on a laboratory table, no special precautions to have a 25 per cent. saturated atmosphere being taken.

The figures for the oxygen absorption test were taken after standing for 4½ days. The last two weighings were very nearly constant. If you wish any of the results duplicated, or if you desire any other further information concerning the samples, I shall be ready to carry out your suggestions.

REPORT OF COMMITTEE E

REPORT OF C. E. WATERS.

Bureau of Standards, Washington, D. C.
(Chemical Work done by Mr. J. B. Tuttle.)

1*d.* SPECIFIC GRAVITY AT 15.5° C.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
0.9338	0.9328	0.9326	0.9342
0.9337	0.9328	0.9322	0.9343
0.9338	0.9328	0.9324	0.9342

1*b.* SPECIFIC GRAVITY AT 25° C.

0.9299	0.9285	0.9286	0.9303
0.9298	0.9286	0.9287	0.9302
0.9298	0.9286	0.9287	0.9302

2. TURBIDITY AND FOOTS IN CUBIC CENTIMETERS.

0.71	0.14	0.21	0.64
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3. BREAKING TEST.

Yes.	No.	No.	Yes.
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4*a.* PERCENTAGE OF MOISTURE AND VOLATILE MATTER.

(Two grams of oil at 105° C. in an atmosphere of CO₂.)

0.01	0.05	0.14	0.00
0.01	0.07	0.12	0.05
0.00	0.03	0.22	0.01
0.10	0.03	0.06	0.03
0.03 gain.	0.05 loss.	0.13 loss.	0.02 loss.

4*b.* PERCENTAGE OF MOISTURE AND VOLATILE MATTER.

Five grams of oil at 100° C. in steam-jacketed oven. Petri dishes, 2½ ins. diameter, were not available, and aluminum dishes 2¼ ins. square, (containing about the same area as 2½-in. round dish) were used instead.

0.014	0.018	0.123	0.035
0.018	0.008	0.138	0.045
0.019	0.012	0.112	0.072
0.012	0.014	0.139	0.054
0.016 loss.	0.013 gain.	0.128 loss.	0.052 loss.

5. PERCENTAGE OF ASH.

0.145	0.035	0.036	0.153
0.133	0.021	0.041	0.156
0.139	0.028	0.038	0.154

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6. DRYING TEST ON GLASS IN HOURS.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
30	30	30	30
Drying not yet complete.			

7. OXYGEN ABSORPTION.

(a) 5 grams PbO.

Per cent.	Hours.	Per cent.	Hours.	Per cent.	Hours.	Per cent.	Hours.
5.46	48	8.11	48	8.38	48	7.46	48
6.23		7.88		9.01		8.39	

(b) 10 grams PbO.

13.65	120	13.40	240	12.09	120	13.32	120
13.79		13.20		13.29		13.68	

The following tests were also made. Test A was made using 5 grams of PbO furnished by the American Society for Testing Materials, while Test B was made with 5 grams Kahlbaum's C. P. Lead Monoxide.

A.	7.06	9.58	11.72	10.30
B.	14.51	13.41	12.95	13.96

8. ACID NUMBER.

1.17	3.71	2.06	1.71
1.14	3.79	2.07	1.69
1.15	3.75	2.06	1.70

9. SAPONIFICATION NUMBER.

(Using 5 grams oil, heating on steam bath 30 minutes.)

		189.7	
190.7	190.2	189.7	190.5
190.6	190.4	189.6	190.5
190.65	190.3	189.67	190.5

10a. PERCENTAGE OF UNSAPONIFIABLE MATTER.

The method used was that given in Bulletin 109, Bureau of Chemistry, using petroleum ether as the solvent.

0.90	0.57	1.03	0.91
	0.65	0.97	0.78
	0.81		
	0.68	1.00	0.84

11. LIEBERMANN-STORCH TEST.

This test gave negative results in each case.

12. REFRACTIVE INDEX.

(Using Abbé Refractometer at 28° C.)

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
1.4780	1.4772	1.4775	1.4775

13. ACETYL VALUE.

5.42	6.20	6.30	4.78
4.63	5.40	4.41	5.43

14. HEXABROMIDE TEST.

The method given in the circular of March 1 was closely adhered to, the only difference being that the determinations were made in glass weighing bottles, $1\frac{1}{8}$ ins. diameter and 4 ins. high.

41.1	36.7	38.6	43.0
41.0	41.1	39.3	43.4
	48.8		

15 IODINE NUMBER.—HANUS METHOD.

185.4	183.7	185.9	184.0
185.2	184.0	186.2	182.6
184.6	183.4	185.9	183.2
184.5	184.0	185.3	
183.3	182.6	184.9	
184.6	182.4	185.1	
183.8			
183.3			
184.3	183.4	185.5	183.3

REPORT OF ARTHUR D. LITTLE, INC.

Laboratory of Engineering Chemistry,
93 Broad Street, Boston, Mass.

In accordance with your circular letter of February 9, we have analyzed the four samples of linseed oil submitted by your Committee and prepared in conformance with its specifications, and present herewith our report. The samples were received sealed and in good condition, and the methods used were those recommended in your circular letter. All tests were made upon oil freshly filtered through dry filter paper immediately before use, at a temperature between 60° and 80° F., unless otherwise noted.

I. SPECIFIC GRAVITY.

The specific gravity was determined by Ostwald pyknometers of the well-known type holding about 10 c. c. Although the Committee recommended that a pyknometer should be used "having a capacity of at least 25 c. c.," our experience has been that more accurate results can be obtained with a pyknometer of the Ostwald type having a capacity of 10 c. c., than with a much larger one of the ordinary bottle type. The temperature factor is the greatest cause of error, and if that could be eliminated, results could be obtained with such a pyknometer accurate to five decimal places. With a small pyknometer, moreover, less oil is forced out of the arms when it is allowed to come to room temperature from 15.5° C. before weighing.

The pyknometer was thoroughly cleaned with chromic acid solution, then rinsed out successively with water, alcohol, and ether, and dried by aspirating through it a current of dry air. Before every weighing it was wiped with a moist cloth and allowed to stand 15 minutes under a bell jar containing a dish of concentrated H_2SO_4 . After weighing empty, it was filled with pure distilled water and placed in a large water bath at 15.5° C., and allowed to remain there one hour. The water was frequently stirred and the bulb of the thermometer was within a fraction of an inch of each pyknometer. For every determination two pyknometers were used. After the weight of water at 15.5° C. had been obtained, the bath was raised to 25° C., the pyknometers allowed to remain one hour in the water at this temperature, and after adjusting the meniscus they were removed, wiped, allowed to stand 15 minutes, and weighed.

The pyknometers were then completely dried as described, and filled with freshly filtered oil. The weight of the oil at 15.5° C. was determined in exactly the same manner as that of the water.

The average difference in the results obtained by the two pyknometers is only 0.0003, and the mean results are probably correct to 0.0002.

STANDARDIZATION OF PYKNOMETERS.

(At 15.5° C.)

Pyknometer.	Average of two.
A.....	9.9997
B.....	11.0291

(At 25° C.)

A.....	9.9882
B.....	11.0124

(a) SPECIFIC GRAVITY AT 15.5° C.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
0.9355	0.9333	0.9336	0.9349
0.9350	0.9336	0.9336	0.9356
0.9352	0.9335	0.9336	0.9352

(b) SPECIFIC GRAVITY AT 25° C.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
0.9299	0.9284	0.9286	0.9299
0.9301	0.9288	0.9288	0.9300
0.9300	0.9268	0.9287	0.9300

2. TURBIDITY AND FOOTS IN CUBIC CENTIMETERS.

After a thorough shaking, 25 c. c. of each sample were introduced by means of long-stemmed funnels into graduated glass tubes about 1 cm. in diameter. The tubes were then stoppered with corks and placed in a vertical position in a light place for two weeks. At the end of that time there was a sediment in the bottom of each tube, as follows:

0.80	0.25	0.30	0.55
------	------	------	------

The stoppers were then removed and the tubes allowed to stand unstoppered for two weeks more. No change was visible.

NOTE.—The sediment from samples Nos. 2 and 3 was gelatinous and would not form a sharp meniscus.

3. BREAKING TEST.

After a thorough shaking, 15 c. c. of each sample were slowly heated in a test tube over a naked flame. A Fahrenheit thermometer was suspended in the oil, and the rise in temperature was less than 90° F. (50° C.) per minute. Each sample was heated up to 572° F. (300° C.), and then the experiment was repeated with a fresh portion of oil.

Breaks about 265° C.	Does not break at 300° C.	Does not break at 300° C.	Breaks about 265° C.
-------------------------	------------------------------	------------------------------	-------------------------

4. MOISTURE AND VOLATILE MATTER.

(a) Loss at 105° C. in a current of CO₂.

The results of this experiment were unsatisfactory and are omitted.

(b) Loss at 100° C. for 2 hours in air.

Portions of about 5 grams of each sample, well shaken but not filtered, were placed in uncovered glass Petri dishes 2 $\frac{3}{4}$ ins. in diameter and heated for 2 hours in a steam oven at 100° C. They were then cooled in a dessicator and weighed. The dishes had been previously heated in the same oven for 2 hours, cooled, and weighed. The results follow:

LOSS AT 100° C., IN PER CENT.

0.059	0.236	0.214	0.016
0.047	0.225	0.219	0.051
0.054	0.231	0.217	0.034

In order to obtain consistent results it seems necessary to follow the foregoing directions very closely. The experiment was first attempted in shallow Petri dishes 4 ins. in diameter, and it was found that in some cases the oil gained in weight instead of losing. The thinness of the layer and the greater surface consequently exposed probably caused oxidation of the oil. The oil should be weighed as soon as cool, since it seems to have a tendency to oxidize in the dessicator after having been heated to 100° C..

5. PERCENTAGE OF ASH.

About 10 grams of each sample, thoroughly shaken but not filtered, were placed in large porcelain crucibles (previously ignited for 15 minutes) and burned to a light gray ash. After cooling the crucibles with the ash in dessicator, they were weighed. The results are tabulated below:

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
0.132	0.030	0.041	0.142
0.138	0.030	0.038	0.143
0.135	0.030	0.040	0.143

It will be noticed that samples Nos. 1 and 4, which show the highest ash, are the same which showed the greatest amount of turbidity. The ash is not alkaline to phenolphthalein.

6. DRYING TEST ON GLASS IN HOURS.

Archbutt's method as described by Gill in the circular of the Committee was followed exactly in preparing the glass plates coated with the oil. The coated plates were then placed under a bell-jar containing a beaker of concentrated sulphuric acid. They were examined several times during the day and the first thing in the morning, and the time was noted when the oil became dry to the touch.

140

120

100

160

7. OXYGEN ABSORPTION, USING LEAD MONOXIDE.

The method described in Bulletin 109, page 7, of the Department of Agriculture, Bureau of Chemistry, was followed as closely as possible. Not being able to obtain suitable dishes of aluminum, however, we used tin dishes of the prescribed size and shape. These were thinly coated on the inside with paraffine to prevent any contact of the tin with the lead monoxide. After the experiment, the paraffine was removed and the dishes were examined. Of the 16 dishes used, only 2 or 3 showed a few dark spots on the tin. Two sets of experiments were carried out: (a) using 5 grams of PbO; and (b) using 10 grams of PbO. The PbO was weighed out on a watch glass and placed in the dishes in as even and flat a layer as possible, completely covering the bottom of the dish. About 0.7 gram of the oil was then spread in drops as evenly as possible

over the surface of the PbO. The exact weight of oil was determined by the loss in weight of a dropping bottle containing the sample of freshly filtered oil. (It may be mentioned here that these dropping bottles were found very convenient in these experiments for weighing out exact quantities of oil from 0.1 to 5 or 10 grams. They are provided with a ground glass joint into which fits a dropper, easily filled and emptied by means of a small collapsible rubber nipple, on the principle of a fountain pen filler. The bottle holds about 1 fluid ounce and the dropper when filled delivers about 1 gram.) The dish with PbO and oil was then weighed exactly. Two dishes were prepared as above with each sample of oil and 5 grams of PbO, and two of each sample with 10 grams of PbO, respectively. They were all placed under a large sheet of plate glass, elevated about 1 in. above the table, having a free access of air in a light place. Each dish was weighed every morning and evening.

One dish of each sample (marked A in the following tables) was started in the morning and one of each sample (B in the tables) late in the afternoon, to determine whether the gain was as rapid in the dark as in the light. We give the results obtained and will discuss them later in this report. The figures represent the percentage of gain in weight based upon the weights of the oil taken.

(a) *With 5 grams of lead monoxide.*

TABLE I.—SET A, FIVE GRAMS PbO.

Sample No.	Weight of Oil, grams.	Gain in Weight in — Hours, per cent.										
		7	24	30½	46½	57	71	78½	95	106	120	169
1	0.6819	0.19	4.22	7.23	8.73	9.46	9.96	10.09	10.29	10.61	10.75	....
2	0.8615	1.62	3.13	3.42	3.55	4.05	4.13	4.39	4.63	4.81	4.97	....
3	0.6286	2.04	7.91	8.48	8.73	9.42	9.55	9.70	....	....	....	11.24
4	0.7320	1.10	6.15	6.91	7.24	7.81	8.03	8.14	8.33	8.54	8.81	9.76

TABLE II.—SET B, FIVE GRAMS PbO.

Sample No.	Weight of Oil, grams.	Gain in Weight in — Hours, per cent.								
		7	24	41	51	65	72½	89	100	114
1	0.6731	1.77	5.70	8.20	8.72	8.72	.....	.....	.....	.....
2	0.7890	3.71	4.61	5.10	5.54	5.91	6.10	6.32	6.64	6.88
3	0.6311	6.20	7.58	8.29	8.81	8.97	9.18	9.16	.....	.....
4	0.6760	5.49	5.82	7.47	8.03	.....	.....	.....	.....	.....

In Table II, samples Nos. 1 and 3 were discontinued because they appeared to have reached a maximum, and No. 4 because of an accident. It will be noted that the gain in every case after about 60 hours had elapsed was very slow.

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These four tables show several interesting results. With 10 grams of PbO a definite maximum gain is obtainable, and with each sample this is reached in about 65 hours. The gain is slow at first and then very rapid, coming within 1 per cent. of the maximum in every case inside of 36 hours. With 5 grams of PbO the gain is also fairly rapid for the first 36 hours, although considerably less than when 10 grams of PbO are used; and after this period the oil continues to gain in weight very slowly for a long time. In view of the quick and consistent results obtained with 10 grams of PbO, it seemed to us hardly worth while to carry the experiments with 5 grams of PbO beyond 5 or 6 days. Two

(b) *With 10 grams of Lead Monoxide.*

TABLE III.—SET A, TEN GRAMS PbO.

Sample No.	Weight of Oil, grams.	Gain in Weight in — Hours, per cent.						
		6	23	29½	45	55	69	76½
1	0.6402	0.75	9.19	12.68	13.51	14.03*	13.75	.....
2	0.7991	1.52	11.16	11.70	12.12	12.56	12.84*	12.84
3	0.6430	0.75	11.30	11.81	12.55	12.83*	12.80	.....
4	0.6245	2.32	12.60	13.19	13.71	14.01	14.08*	.....

TABLE IV.—SET B, TEN GRAMS PbO.

Sample No.	Weight of Oil, grams.	Gain in Weight in — Hours, per cent.					
		17	24	41	51	65	72½
1	0.6578	3.19	10.45	13.30	13.87	14.02*	13.93
2	0.7323	10.81	12.00	12.43	12.80	13.04*	13.01
3	0.6862	10.26	12.32	12.83	13.07	13.20*	13.20
4	0.6674	9.95	11.90	12.40	12.90	13.00*	12.97

samples were allowed to run for 7 days, but at the end of that time they did not appear to have reached a maximum, and at the rate at which they were proceeding would have required several more days to have reached the maximum which the same samples showed with 10 grams of PbO in 2½ to 3 days.

The oil takes up oxygen more rapidly in the light than in the dark, as will be seen by comparing Tables III and IV. In Table III, three of the samples reached their maximum in 55 hours, of which 33 hours were light and 22 were dark. In Table IV, the samples reached practically the same maxima in 65 hours, of which 32 hours were light and 33 were dark. The samples in the latter table, as has been stated, were started late in the afternoon.

* Maximum

In reporting our results we shall omit the experiments with 5 grams of PbO.

7b. OXYGEN ABSORPTION, 10 GRAMS PbO.

Sample No.	Maximum, Started in Morning—(A).		Maximum, Started in Evening—(B).	
	Time, hours.	Gain, per cent.	Time, hours.	Gain, per cent.
1	55 (about)	14.03	65 (about)	14.02
2	65 "	12.84	65 "	13.04
3	55 "	12.83	65 "	13.20
4	60 "	14.08	65 "	13.00

In our opinion the best method of applying this test in comparing different oils is to use 10 grams of PbO and about 0.7 gram of the oil. The test should then be allowed to run a definite length of time; and since the oxidation proceeds more rapidly in the light, it is sooner finished if started in the morning. Under these conditions the samples will have reached their maximum gain (within a few tenths of one per cent. at any rate) by the third afternoon, say in 55 hours. For all practical purposes of comparison, however, 48 hours will be sufficient, if the experiment is started in the morning. This is the length of time recommended in Bulletin 109. If started in the afternoon, they should be allowed to run somewhat longer.

8. ACID NUMBER.

The method described in Bulletin 107, page 142, of the Department of Agriculture, Bureau of Chemistry, was followed. The results are expressed in milligrams of KOH per gram of oil. The determinations were made on freshly filtered oil.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
1.24	3.57	1.94	1.74
1.16	3.58	1.96	1.68
1.20	3.57	1.95	1.71

9. SAPONIFICATION NUMBER.

About 5 grams of each freshly filtered sample were placed in a 300-c. c. Jena Erlenmeyer flask and saponified for one hour under a reflux condenser with 50 c. c. of alcoholic KOH. Two blanks were run with each set of determinations (A, B, and C, respectively). The blanks and samples were then titrated with $N/2$ H_2SO_4 , using phenolphthalein as an indicator.

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9. SAPONIFICATION NUMBER (CONTINUED).

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
192.8	192.8	191.7	194.1
193.8	193.2	193.0	194.3
193.5	193.4	193.3	194.8
193.4	193.1	192.7	194.4

The saponification number represents the number of milligrams of KOH required for 1 gram of the oil.

10. UNSAPONIFIABLE MATTER.

Boemer's method as described in the circular of the Committee was followed exactly, using freshly filtered oil.

The unsaponifiable matter was boiled with about an equal weight of acetic anhydride for 2 hours in a regular acetylation flask—a small oval-shaped flask having ground into the neck a long glass tube which serves as an air-cooled reflux condenser. The unsaponifiable matter dissolved in the anhydride while hot, but crystallized out on cooling. The hot solution was poured into a beaker of water and a yellowish oily mass separated. This was boiled with several portions of water, decanting the water each time, until the latter was no longer acid to litmus. The residue was then dissolved in hot alcohol, from which, on cooling, white clusters of fine crystals separated. Their melting point was then determined by the mercury method. One or two crystals were placed on the clean surface of mercury contained in a nickel dish and covered with a clean glass such as is used on microscope slides. The bulb of a thermometer was completely immersed in the mercury and the latter slowly heated with a micro-burner. The crystals were observed through a large lens and the temperature at which they began to melt was noted and taken as the melting point. The temperature at which the crystals completely melted is also given in the following table, being generally 1° or 2° higher.

(a) PER CENT.

0.943	0.924	0.942	0.943
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(b) MELTING POINT, DEGREES CENTIGRADE.

128	105	103	102
(130)	(106)	(105)	(104)

11. LIEBERMANN-STORCH TEST.

The test was carried out in exact accordance with the directions given in Bulletin 109 of the Department of Agriculture, Bureau of Chemistry. None of the samples gave the fugitive violet color characteristic of rosin or rosin oil. Each, however, gave a permanent coloration varying from greenish black to reddish green. The test gave negative results in each case.

12. REFRACTIVE INDEX AT 25° C.

The refractive index was determined with a Zeiss Abbé refractometer at 25° C. on portions of the freshly filtered oil. In each case readings were taken on more than one portion of each sample. These readings are as follows:

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
1.4798	1.4796		1.4801
1.4798	1.4796	1.4800	1.4799
1.4798	1.4794	1.4800	1.4802
1.4802	1.4794	1.4799	1.4800
1.4799	1.4795	1.4800	1.4800

13. ACETYL VALUE.

The Benedikt-Lewkowitsch method as described in Bulletin 107, revised page 142, was followed. Twenty-five c. c. of the filtered oil were boiled in a beaker with an equal volume of acetic anhydride for 2 hours. It was found necessary to add more anhydride from time to time to replace the loss by boiling. This mixture was then poured into a large beaker containing 500 c. c. of water and boiled 30 minutes, with a small stream of CO₂ passing into the water near the bottom to prevent bumping. The water was siphoned off, fresh water added, and the process repeated several times until the water was no longer acid to litmus. The acetylated oil was separated as completely as possible from the water in a small separatory funnel and filtered hot through a dry filter in a steam-jacketed funnel. It was then dried at 105° C. for about an hour.

About 3 or 4 grams of the acetylated oil were weighed from a dropping bottle into a 300-c. c. Erlenmeyer flask, and to this were added 50 c. c. of N/2 alcoholic KOH, the exact equivalent of which in terms of N/2 H₂SO₄ was later determined by titration. This was saponified for one hour under a reflux condenser. The alcohol was next evaporated off completely and the soap dissolved in water. To this solution was added the amount of N/2 H₂SO₄ equivalent to the alcoholic KOH previously added, and the flask was warmed on the steam bath until the two layers had separated. The contents were filtered hot through a wet filter and the oil was washed with boiling water until the filtrate was no longer acid to litmus. Finally, the filtrate was titrated with M/10 KOH and phenolphthalein. The acetyl value is the number of milligrams of KOH required in this process by 1 gram of the acetylated oil. The results obtained follow:

40.6	47.6	51.9	54.0
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Although the directions in Bulletin 107 read: "Boil the oil or fat with an equal volume of acetic anhydride for two hours," it seemed to us that if this were done in an open beaker or flask there would be con-

siderable danger of oxidation. This oxidation would probably mean the formation of new hydroxyl groups in the oil molecules, and these in turn would exchange their hydrogen for an acetyl group, with the result that the acetyl value found would be too high. Moreover, we find that Benedikt and Lewkowitsch* direct that for the determination of the acetyl value of *fatty acids*, boil with an equal volume of acetic anhydride for two hours "in a round-bottomed flask attached to an inverted condenser." Accordingly, we repeated the previous experiment, boiling the oil and the anhydride for two hours under a reflux condenser. The rest of the analysis was carried out exactly as above described with the acetylated oil. The results obtained, which are given below, were only about half those previously obtained and would seem to show that it is not safe to acetylate the oil except under a reflux condenser. It is believed that the following values are the correct acetyl values of the samples, and we omit those first found from the final summary of this report:

21.4 27.8 25.0 30.5

14. HEXABROMIDE TEST.

Tolman's method as described in the circular of the Committee was followed as closely as possible. The results, however, were very unsatisfactory. The weighing bottles used were only about 4 ins. high and consequently permitted the addition of only about 20 c. c. of absolute ether. Otherwise, the analysis was carried out as the circular directed. Three series of tests (A, B, and C) were made, with the following results:

Sample No.	Series A.		Series B.		Series C.	
	Hexa-bromide, per cent.	Melting Point of Hexa-bromide, in °C.	Hexa-bromide, per cent.	Melting Point of Hexa-bromide, in °C.	Hexa-bromide, per cent.	Melting Point of Hexa-bromide, in °C.
1	35.1	118	58.32	118.5	47.23	118
2	30.4	119	52.66	119	41.31	121
3	31.5	119	52.77	119	44.15	120
4	28.9	119	58.93	119	42.88	120

The discrepancies in the results are so very large that we omit this test from the general summary of our report.

15. IODINE NUMBER.

Hanus Method.—The directions given in Bulletin 107, page 136, were followed. The thiosulphate solution was standardized with the sample of pure $K_2Cr_2O_7$ furnished by the Committee. About 0.2 to

* Chemical Analysis of Oils, Fats and Waxes, 1895 edition, page 128.

0.25 gram of the freshly filtered oil was weighed from a dropping bottle into a wide-mouthed 16-oz. bottle provided with a ground glass stopper. To this were added 10 c. c. of pure chloroform and then 25 c. c. of the Hanus solution from a pipette. The bottle was stoppered and allowed to stand, with occasional shaking, for 30 minutes. Fifteen c. c. of 10 per cent. KI solution were then added; after shaking, 100 c. c. of water were added and the iodine was titrated with the N/10 thiosulphate solution. Care was taken to keep the temperature as nearly constant as possible during the analysis and two blanks were run with each set of analyses. The results follow:

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
187.7	184.8	187.3	190.6
187.7	186.3	189.0	188.1
187.7	185.6	188.2	189.3

Wijs Method.—The iodine number was also determined by means of the Wijs solution, in order to compare the results obtained by the two methods. This is the method in use in this laboratory for the determination of iodine numbers.

The Wijs solution was made up by dissolving 13.2 grams of iodine in glacial acetic acid (99.5 per cent.), and then passing chlorine gas into the solution in sufficient quantity to double the halogen content. The point at which this takes place is shown by a change in color of the solution from a dark brown to a considerably lighter brownish red.

About 0.2 to 0.25 gram of the oil was weighed out into the same kind of a bottle as previously described, and to it were added 10 c. c. of chloroform and 25 c. c. of Wijs solution from a pipette. After standing tightly stoppered for one hour, 40 c. c. of a 10 per cent. KI solution were added and the iodine was titrated with the same N/10 thiosulphate solution as was used in the Hanus method. Two blanks were run and the same precautions against change in temperature were observed. The results are given below:

189.2	185.1	188.8	187.4
189.8	184.0	189.3	186.8
189.5	184.6	189.1	187.1

ADDITIONAL ANALYSES.

The specifications adopted by the Treasury Department in Washington in 1907* state with regard to linseed oil, that it "shall conform to the following physical and chemical tests: Specific gravity at 15.5° C., not less than 0.933; flash point (open cup), not less than 280° C.;

* See Holley and Ladd: Mixed Paints, Color Pigments and Varnishes, 1908 edition, page 66.

viscosity at 20° C., as determined by the Engler viscosimeter (water being 100), not less than 750; iodine absorption number as determined by Wijs' method (time of absorption two hours), not less than 175; to be entirely free from all acids except fatty acids, of which not more than 2 per cent. calculated as linolic acid should be present,* when heated to 300° C. and allowed to cool, the oil should show no suspended matter or deposit, and must show excellent drying qualities, as demonstrated by the Livache method."

The only tests in these specifications which are not included among those prescribed by the Committee in their circular, are the viscosity and flash tests. It seemed advisable, therefore, to make these tests upon the samples submitted, and we here include the results obtained.

VISCOSITY.

The determination of the viscosity was carried out in a Saybolt Universal Viscosimeter instead of the Engler, which was not available. The jacket bath of the instrument was brought to 20° C. and the well-shaken but unfiltered sample of the oil was also brought to this temperature. The oil was run through the instrument several times, until it no longer contained any bubbles and until two successive determinations did not vary by more than 3 seconds in the time required to fill the 60-c. c. graduated glass flask.

After the four samples of oil had been run, the viscosimeter was thoroughly cleaned and the viscosity of the water determined at 20° C. This was found to be 28, i. e., 60 c. c. of water ran through the orifice in 28 seconds. The results are given as follows:

VISCOSITY AT 20° C.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
3m. 42s.	3m. 50s.	3m. 20s.	3m. 45s.
3 45	3 50	3 22	3 45
224 S.	230 S.	201 S.	225 S.

FLASH POINT.

The flash point was determined by the open cup test. A Fahrenheit thermometer was suspended in the oil and the oil in the cup slowly heated. The temperature at which the first distinct puff of blue flame shot across the surface of the oil when a very small lighted jet was swept across it was taken as the flash point. The results are also calculated to Centigrade readings. The oil was not filtered.

575° F.	560° F.	580° F.	583° F.
302° C.	293° C.	304° C.	306° C.

* This corresponds to an acid number 4.5.

In the summary of this report, the results of Test 4a—loss at 105° C. in CO₂, and Test 14—Hexabromide Test, are omitted, as the results are unsatisfactory and are not, in our opinion, reliable. In cases where duplicate or triplicate analyses were made, the average figure has been taken.

REPORT OF A. P. BJERREGAARD.

Agricultural Experiment Station, New Mexico.

This work was done by the methods suggested in the printed circular received, except as herein stated. The specific gravity was determined in a 50-c. c. pyknometer with a thermometer in the stopper.

1a. SPECIFIC GRAVITY AT 15.5° C.

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
0.9348	0.9325	0.9330	0.9340

1b. SPECIFIC GRAVITY AT 25° C.

0.9296	0.9331	0.9285	0.9294
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2. TURBIDITY AND FOOTS IN CUBIC CENTIMETERS.

0.50	0.20	0.30	0.50
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3. BREAKING TEST.

The breaking test was made by heating 15 to 20 c. c. of the oil to 300° C. in test tubes immersed in an oil bath, and maintaining that temperature for one hour. The results follow:

Breaks.	Does not break.	Does not break.	Breaks.
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This method was employed to make an observation on the amount of thickening produced by this treatment, and the color of the thickened product. This is a very important test from the varnish makers' point of view.

Samples Nos. 1 and 4 became very heavy in body, as heavy as a standard sample known to be used by a large varnish firm; No. 2 was much thinner, and No. 3 still thinner. After cooling, a penetration test on porous paper was made, No. 2 penetrating a little better than any of the others.

All the samples showed a strong green fluorescence; No. 2 was darkest in color, No. 3 was next, and Nos. 1 and 4 were palest, while No. 4 was greener in tint than No. 1. When viewed across the thickness in the test tube, Nos. 1, 3, and 4 were paler than when raw, while No. 2 was practically the same color as when raw.

4. MOISTURE AND VOLATILE MATTER.

The determination of the moisture and volatile matter was made in two ways. First, about 4 grams of the oil were weighed into 200-c. c. Erlenmeyer flasks provided with rubber stoppers carrying the necessary glass tubes; all the flasks were then arranged in one train, immersed in a calcium chloride solution, dry hydrogen passed through, and when all the air was displaced, the oil was heated to 110° C. while the hydrogen stream was continued for 3 hours. Care was taken to permit the glass to reach moisture equilibrium in the balance case by letting it stand therein over night before weighing. A gain in weight was observed with Nos. 1, 2, and 4, and a slight loss with No. 3. It was thought that this gain might have resulted from traces of air entering the apparatus while adding acid to the zinc in the evolution flask, and thereby causing oxidation of the oil. Later results in drying oil on litharge do not sustain this view, because there was no gain in weight of the oil and litharge in 5 hours.

Another series of moisture determinations was then tried, this time in open dishes placed in the water-jacketed hydrogen oven. Both porcelain and platinum dishes were used, but no difference can be seen in the results. The oven was filled with dry hydrogen free from air before beginning to heat it, and care was taken to pass a rapid stream of the same dry hydrogen throughout the 5-hour drying period, and the whole night while the apparatus was cooling down. Here also a gain in weight is observed with Nos. 1 and 4 and one of the duplicates of No. 2, and a loss in weight with No. 3 and the other duplicate of No. 2.

The gains are much smaller in this series, however. A plausible explanation of these gains appears to be that hydrogen gas is soluble in and is absorbed by the oil. To test this hypothesis, experiments were started to dry the oil in an atmosphere of dry Co_2 , but they were spoiled by an accident, and lack of more unfiltered oil prevented a repetition.

The oils in the flasks from the first drying experiment were heated with free access of air in an oven to 110° for $2\frac{1}{2}$ hours. Very substantial gains in weight were obtained.

The results of this test are as follows:

(a) PERCENTAGE OF MOISTURE AND VOLATILE MATTER IN HYDROGEN.

(Allowing to stand over night before weighing.)

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
0.10 gain	0.13 gain	0.08	0.08 gain

(b) DRYING IN HYDROGEN OVEN.

0.05 gain	0.00	0.18	0.01 gain
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5. PERCENTAGE OF ASH.

0.156	0.047	0.048	0.159
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6. DRYING TEST ON GLASS IN DAYS.

Archbutt's drying test on glass was carried out as directed. On account of the impossibility of placing the glass slips absolutely horizontal, the oil became irregularly distributed on them. The results recorded are for the thicker places on the glass. At the same time a series of drying tests on glass by the ordinary factory method was carried out. That is to say, the oil was spread over the glass, which was then set nearly vertical, so that the excess of oil could drain away. All of the oils dried more quickly by this method than by Archbutt's. The results, giving the time in days, are as follows:

(a) *Glass Horizontal.*

Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
Over 7	Over 6	Over 6	Over 7
	4	6	7

(b) *Glass Vertical.*

4	3	3½	4
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7. OXYGEN ABSORPTION.

In the test of the oxygen absorption on lead oxide, ordinary flake litharge was used instead of the sample sent, because the latter was not in sufficient quantity. Tin dishes $2\frac{1}{2}$ ins. wide and $\frac{3}{8}$ in. deep (tops of preserve glasses), were used because we had no aluminum trays. No suitable place free from dust and exposed to light was available, so these trays were kept in a rather tight drawer during the test, and therefore in the dark. A very great difference in the rate of drying was found between oil on 5 and on 10 grams of the litharge. The gains in weight have been calculated to percentage of the original weight of oil and tabulated. The results are given in the accompanying Tables I and II.

(a) 5 grams litharge.

Per cent.	Hours.	Per cent.	Hours.	Per cent.	Hours.	Per cent.	Hours.
6.28	540	5.11	540	6.74	540	6.86	540

(b) 10 grams litharge.

15.04	277	11.53	540	14.64	277	15.17	277
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8. ACID NUMBER.

1.21	3.49	1.91	1.57
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9. SAPONIFICATION NUMBER.

184.5	183.7	183.7	185.5
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ON PRESERVATIVE COATINGS FOR STRUCTURAL MATERIALS. 201

TABLE I.—DRYING OF OILS ON LITHARGE, SAMPLES 1 AND 2.
Per cent. gain in weight of oil.

Time in Hours.	Sample No. 1.			Sample No. 2.			
	Weight of PbO used, grams.			Weight of PbO used, grams.			
	5.	5.	10.	5.	5.	10.	10.
24	0.44	0.65	0.66	1.75	1.99	7.53	7.81
32	1.31	1.65	4.08	3.26	3.62	8.00	8.35
48	3.08	3.42	9.84	3.71	4.06	8.54	8.83
55	3.60	3.92	11.03	3.80	4.19	8.82	9.12
84	4.37	4.62	12.53	3.87	4.29	8.97	9.28
108	4.88	5.15	13.80	4.07	4.52	9.42	9.63
115	4.91	5.18	13.96	4.08	4.56	9.46	9.66
132	4.97	5.28	14.37	4.14	4.63	9.67	9.88
180	5.06	5.39	14.70	4.30	4.87	10.06	10.18
204	5.06	5.41	14.78	4.35	4.92	10.25	10.40
228	5.06	5.48	14.89	4.44	5.01	10.44	10.55
252	5.10	5.52	14.95	4.53	....	10.53	10.68
277	5.10	6.06	15.04	4.59	....	10.73	10.84
302	5.17	6.08	15.01*	4.61	....	10.80	10.90
348	5.17	6.08	14.99*	4.64	....	10.93	11.00
396	5.24	6.16	15.02	4.84	....	11.13	11.22
444	5.27	6.21	14.97*	4.92	....	11.24	11.30
540	5.26*	6.28	14.97	5.11	....	11.46	11.53

TABLE II.—DRYING OF OILS ON LITHARGE, SAMPLES 3 AND 4.
Per cent. gain in weight of oil.

Time in Hours.	Sample No. 3.				Sample No. 4.			
	Weight of PbO used, grams.				Weight of PbO used, grams.			
	5.	5.	10.	10.	5.	5.	10.	10.
24	1.84	1.52	6.19	5.18	1.57	1.36	4.35	4.92
32	3.09	2.75	9.54	8.39	2.75	2.60	7.11	8.56
48	4.63	3.90	10.18	10.08	4.27	4.44	10.13	11.97
55	5.16	4.15	10.79	11.61	4.62	4.91	....	12.74
84	5.53	4.22	13.54	12.13	5.01	5.52	11.52	13.47
108	5.94	4.47	14.14	12.59	5.42	5.99	12.18	14.31
115	5.99	4.63	14.20	12.67	5.42	6.00	12.13*	14.43
132	6.07	4.67	14.31	12.89	5.48	6.08	12.34	14.76
180	6.20	4.80	14.39	13.13	5.51	6.17	12.60	15.00
204	6.25	4.84	14.47	13.31	5.58	6.25	12.73	15.09
228	6.31	4.93	14.56	13.45	5.62	6.30	12.87	15.10
252	6.35	4.99	14.57	13.49	5.67	6.37	12.95	15.10
277	6.39	5.06	14.64	13.65	5.75	6.43	13.08	15.17
302	6.45	5.11	14.60	13.61*	5.75	6.47	13.12	15.12*
348	6.49	5.17	14.54*	13.61	5.79	5.53	13.17	15.04*
396	6.58	5.29	14.54*	13.73	5.87	6.64	13.14*	15.02*
444	6.63	5.38	14.50*	13.73	5.89	6.71	13.17	14.90*
540	6.74	5.56	14.44*	13.73	6.00	6.86	13.29	14.81*

* Loss of weight.

10. UNSAPONIFIABLE MATTER.

In the determination of unsaponifiable matter, it was found that 100 grams were far too large a quantity to handle conveniently. In the absence of a 2000-c. c. separatory bulb, the soap solution was divided into two equal parts, and a 1000-c. c. separatory used. After six extractions the well-washed sixth ethereal extract still contained large quantities of matter in solution. Lack of time has prevented further work with smaller quantities of the oils.

The remaining tests were not made, due either to lack of instruments or of time.

APPENDIX II.

REPORT OF JOINT SUB-COMMITTEE OF COMMITTEES E AND U ON INVESTIGATION OF THE INHIBITIVE POWER OF CERTAIN PIGMENTS ON THE CORROSION OF IRON AND STEEL.

The Sub-Committee appointed from Committees E and U held two meetings during the year. It was determined to purchase in the open market fifty different pigments representing material in ordinary use. Small samples of these pigments were distributed among various chemists for testing, according to the method suggested by Mr. G. W. Thompson, as described by Mr. A. S. Cushman in the Proceedings of the last Annual Meeting, Vol. VIII, pp. 605-610. These tests consisted of putting carefully weighed samples of different kinds of steel into bottles connected together in the same manner as a train of wash-bottles, equal quantities of the different pigments to be tested being inserted in the successive bottles, together with an equal volume of water. Air was then bubbled in for various lengths of time, after which the samples of steel were removed, cleaned with a brush, dried, and re-weighed. The condition of the surface and the loss in weight were noted. These tests were made independently and simultaneously by five different chemists, and the results were plotted and compared. From these comparisons the pigments were divided by your Committee into three classes, which were tentatively called "inhibitors, indeterminates, and stimulators." From these, ten inhibitors and nine stimulators were selected, but this selection was made only when the five experimenters were unanimous in finding that the substances had fallen into these respective classes. In all cases in which there was lack of agreement among the experimenters, the pigments were eliminated from further consideration.

To determine the value of these laboratory tests, the Paint Manufacturers' Association agreed to erect on a piece of land

leased by them at Chelsea, a suburb of Atlantic City, a number of steel plates for making practical service tests. The paints used were single pigments from the inhibitor, indeterminate, and stimulator classes, also composite pigments and variations in pigments used in the several coats so as to obtain a theoretical inhibitor under coat and an excluding final coat, all ground in the same vehicle. The steel plates were rolled from Bessemer steel, basic open-hearth steel, and a special pure iron.

The exposure of these panels has been too short to give positive indications of the value of these tests, and it would be premature to make any statements at this time. In the opinion of the Committee, however, the results of these tests will be of great practical value, owing to the care with which uniformity of conditions has been maintained and recorded. The Committee wishes to express its high appreciation of the assistance rendered by the Paint Manufacturers' Association and the steel manufacturers, which has made these tests possible.

Respectfully submitted on behalf of the Joint Committee,

S. S. VOORHEES,
Chairman pro tem.

DISCUSSION.

MR. H. E. SMITH.—With regard to the report of the Committee on Linseed Oil, the values of the specific gravity are given at 15.5° C., which has the support of long practice; but 20° or 25° C. would really be more convenient. Mr. Smith.

MR. G. W. THOMPSON.—Tests were made both at 15.5° and 25° C. The Committee felt it would not be safe to condemn 15.5° and establish 25° ; so they used both. It is easier to make a determination at 25° than at 15.5° , as is borne out by the fact that there is a better agreement between analysts at 25° than there is at 15.5° . Mr. Thompson.

MR. G. D. WHITE.—I would like to ask Committee E one question: I recently examined the Havre de Grace bridge, and it would appear from a superficial examination that the paint on the bridge is wearing better than that on the test plates. I was wondering whether the Committee has come to that same conclusion; and if so, whether they have any reason to advance for that condition. Mr. White.

MR. S. S. VOORHEES.—We found that was true in one or two cases, but the difficulty of making a thorough inspection of all parts of the bridge is such that we were not justified in making a statement as to the bridge itself. We feel that the paints, as a rule, are in good condition. They need, however, a longer time to give any positive data and we hope, as stated, that photographs will be made of all of the panels and perhaps of some sections of the bridge, and that one of the steel plates in each set exposed will have the paint removed in order that photographs may be made of the metal underneath. Mr. Voorhees.

MR. C. D. RINALD.—I have not examined the bridge, but I have been told by a practical painter that the balance of it appears to be in better condition than the panels on which the tests have been made. This is disappointing news because when those panels were started I felt rather sanguine about the Society's chances of getting tangible results regarding the behavior of the different paints when used on a large scale. For twenty years or

Mr. Rinald.

more I have carried on laboratory tests with all the more prominent paints in the market, in an endeavor to arrive at reliable conclusions for my own use. The results are such that I am less positive now of my knowledge than I was before starting them. It is a curious fact, supported by the experience of others as well as myself, that laboratory experiments, no matter how carefully made, do not give the same results as obtained in actual use. I had hoped that in this case, where the conditions for forming reliable conclusions were so nearly ideal, the field tests and laboratory tests would show a better agreement, but it seems to me now that such will not be the case.

In that connection I would like to say with regard to the tests that I have been making right along in a small way, that every now and then instances came up where purchasers wanted a guarantee that a certain grade of paint would stand certain exposure. We always refuse to give such guarantees even though we feel justified in telling them, "Go ahead, probably it will stand it." I would then start in and conduct exposure tests and continue them for two or three years. I remember some which did not come out very satisfactorily, so that I went to the special bridge or building in fear and trembling, afraid that the paint must have perished. I found, on the contrary, that it had stood much better than my experiments had indicated. This has happened repeatedly and not knowing how to account for it, I should welcome an explanation. It seems to me that when you use paint on a large scale it forms a homogeneous mass, and thus where you have everything covered with the same kind of paint it will often last much longer than where you have it on small surfaces only.

Mr. Thompson.

MR. THOMPSON.—I think it would be unfortunate for the statement of Mr. White to be uncontested. I am not willing to admit what Mr. White has said. I have seen those plates a good deal and have seen the bridge a good deal, and I am not willing to admit that the plates are not showing as good results as the bridge. It must be remembered that the plates are in some respects more exposed than the bridge; but so far as you can see the paints are doing good work on the plates at the present time. There is not one of them which has not given good protection. I am not speaking for the Committee, but simply as an individual as to what I have seen. I can simply put my opinion at this time against

Mr. White's. I will explain what may, perhaps, not be understood, that there were nine test plates painted for each paint. These were placed right alongside of the corresponding panels of the bridge. Now I want to ask Mr. White if he refers to the rest of the bridge, or to that part of the bridge opposite the panels? Mr. Thompson.

MR. WHITE.—I referred to the part of the bridge opposite the panels. Mr. White.

MR. THOMPSON.—The rest of the bridge was not painted under the jurisdiction of the Committee at all. There were nine panels painted, using each paint; three of them spread at 1,200, three at 900, and three at 600 sq. ft. to the gallon. I think the report of our Committee will show that those painted 1,200 sq. ft. will not stand as well as those painted 600 sq. ft. It is possible, as Mr. White says, that the paint on the bridge may have been spread nearer 300 sq. ft. We are unable to calculate properly the spreading rate on the bridge, because the paint on the edges of a member may be $\frac{1}{8}$ in. thick on account of the running and the impossibility of spreading it smoothly. Mr. Thompson.

MR. VOORHEES.—In regard to the statement that the paint on some of the panels was possibly not standing as well as the same paint on the bridge proper, I may state this as an individual opinion, as in one or two cases I had reason to believe that the film on the panel was more brittle than that on the bridge proper; but in comparisons of this sort you are assuming that conditions are uniform, and it would not be fair to make a positive statement on an individual panel. At certain points it might be true; but that it would hold all over the panel or all over the bridge, has not been established. Mr. Voorhees.

MR. RINALD.—There are a good many independent tests going on. There is a gentleman here, I do not know that I am at liberty to mention his name, who showed me a series of tests which are extremely interesting. He had a very large number of samples in each test, only small pieces of iron, but in each case he had scratched the piece before the paint was quite dry with a wire nail diagonally across the corner but not all the way across, just leaving a little ridge at the corners. It was very interesting, indeed, to see how in some cases the rust worked its way under the paint, lifting it off; while in others the paint seemed to act Mr. Rinald.

Mr. Rinald. as an inhibitor so that there was scarcely any rusting, even on the bare metal.

Mr. Gardner. MR. H. A. GARDNER.—I think Dr. Walker, of the Massachusetts Institute of Technology, has brought forth a very interesting point in this matter. He has shown that when the surface of linseed oil applied to a steel plate becomes abraided, corrosion of the steel is stimulated. The hydrogen which is formed during the corrosion is rapidly removed by the linseed oil coating, which is an unsaturated compound, and this removal of hydrogen allows free corrosion to proceed. When a plate painted with red lead is scratched to the steel no corrosion seems evident, because red lead is an inhibitive pigment; whereas if the plate is painted with stimulative compounds scratching causes corrosion. To develop this fact the Paint Manufacturers' Association, acting under the advice of Committee E, have placed a scratch on the upper right hand corner of all the plates painted on the steel test fences at Ventnor, N. J. Three months later an inspection will be made to learn the condition of the various steel plates as affected by this test.

Mr. Evans. MR. S. M. EVANS.—We hear again those familiar words, "stimulators and inhibitors." I remember last year we had considerable discussion on this subject, with some reference to the possible insulating effect of the linseed oil film in these so-called stimulative paints. I should like to know if anybody can throw any further light on that aspect of the question. Have any results been obtained corroborative or otherwise of the theory that the linseed oil film itself acts as an insulating agent?

Mr. Gardner. MR. GARDNER.—It does for a certain length of time. However, as soon as the linseed oil coating is subjected to sufficient exposure it will break down and galvanic currents will be set up causing active corrosion to proceed. To prove this point I attached a copper plate to either end of a paint film made of stimulative carbon pigments, and to the end of the copper plates I attached wires running to a battery, and placed a galvanometer in the circuit. There was no passage of current through the paint film, the linseed oil acting as a non-conductor. The paint film was then subjected to a treatment with water, and after the film had soaked up considerable water it was again placed in the circuit. Deflections of the galvanometer showed that a passage of current

was taking place. This seems to show that corrosion of steel painted with pigments which are good conductors of electricity is imminent. This experiment also shows that as long as the linseed oil coating remains dry and intact no current will pass through; but as soon as it takes up enough moisture and becomes disintegrated, the current passes and corrosion proceeds. Mr. Gardner.

MR. EVANS.—That would seem to be a very good test for the classification of pigments as suggested by Mr. Voorhees. Mr. Evans.

MR. GARDNER.—I think so, but we have not yet worked it out fully. Mr. Gardner.

MR. P. FIREMAN.—I would like to say a few words with regard to the joint report of Committees E and U. I can hardly admit that the experiments carried out have been rationally arranged, and that the results are of a nature that can be easily assimilated. Mr. Cushman especially taught us that soluble material in paint is its greatest enemy, the cause of corrosion, and all that sort of thing. Now he himself goes ahead and takes up a whole lot of pigments pell-mell; we know nothing about them, whether they contain soluble material or not, and what can be expected under such conditions but that the results will be more or less indefinite? Are the injurious effects due to the pigments, or due to the impurities? To my mind the entire series of tests, although carried out by a number of investigators, are futile; and the conclusions are also very peculiar, to say the least. We learn that there are certain inhibitors. What are they? When a chemist hears something about chromates he immediately recalls that the chromates are oxidizing agents, and he thinks there must be something in that. He begins to think that the chromates may have some virtue. Now zinc oxide is fully as good an inhibitor as the chromates; and yet it has no oxidizing properties, nor any reducing properties either. In making tests of the kind described, each pigment should be first analyzed and tested for purity; then perhaps we will be able to talk about results, and what they mean. It would have been much better to have taken half a dozen pigments and thoroughly studied them, and to have made tests with them under various conditions, than to take forty or fifty pell-mell, and get results that to my mind are meaningless and misleading. Mr. Fireman

The President.

THE PRESIDENT.—I do not hold any brief for the Committee, and although I am a member of the Committee I did not make any of the tests that are published. I would like to say two things: first, that as opening up a new subject, one absolutely new to all of us, I think, the Committee deserves very great credit. The fact that pigment has an influence on the rate of corrosion of metal is really a stupendous fact to me; and while I might be willing to agree with the last speaker that some of the details of the test, and some of the methods, could be better, I cannot forget the fact that a lot of pigments selected in the market which are being used from day to day, which I understand was the reason why they were taken in this test, do show a very wide difference in their effect on corrosion when treated alike. That fact to me is one of tremendous importance. I do not understand that the Committee regards these tests as final, and I for one am extremely willing to give the Committee every credit and especially Mr. Thompson who originally suggested the experiments.

The second point I wish to speak of is that as a consumer I am in rather a difficult position. Soon after these tests were published I asked for a copy to be sent me, and, being a member of the Committee, it was deemed legitimate that I have a copy. I went over the data very carefully, and our people said to me: "What shall we do? You have been recommending now for a number of years that we should coat our steel with lampblack paints. Here these tests indicate that lampblack is a stimulator of corrosion; now what are you going to do about it?" So you see I have been in rather a tight position. I do not think the Committee feels they have got the final truth yet; hardly a month passes that some new developments do not come up. We are in a period of tremendous transition. So I have said to our people: "Let us hold on to what we have got till we have a little more data under our feet; then we will tell you what we think ought to be done."

Mr. Walker.

MR. P. H. WALKER.—There is one serious objection to the idea that all these pigments before they were tested should have been accurately analyzed; it may be a bad thing for a chemist to get up here and say so, but it cannot be done. The materials that influence corrosion may be present in exceedingly minute quantities. Some of these pigments are made with organic acids;

the chromates themselves, for instance, may contain a small amount of organic salts. A chemist cannot certainly determine that. His errors of analysis will be greater than the impurities affecting corrosion; whereas in performing these experiments on the steel according to Mr. Thompson's plan, we get certain values. The Committee has gone ahead and made practical paint tests without reference to any theory in regard to inhibitors and stimulators. Mr. Walker.

Certain pigments apparently of the same composition may, in reality, behave differently. We had such an experience with two Prussian blues, which gave different results in the tests. I believe one of these blues contained a trace of chromium, and the other did not.

MR. GARDNER.—We scoured the market for the best materials obtainable. In nearly every case I made analyses of the pigment to determine the percentage of soluble matter they contained. In one or two cases very slight traces of acid were found. Mr. Gardner.

It has just been asked why zinc oxide should be regarded as an inhibitor. I think very likely that the inhibitive nature of this pigment is due to the fact that it is soluble to a very slight extent, and being by nature a base, it may assert the inhibitive nature that is common to most bases which in water develop large quantities of hydroxyl ions. We have two soluble materials on the test fence. One is zinc chromate, and this is a very good inhibitor; the other is calcium sulphate, and this is a very active stimulator. Both these materials are soluble to a certain extent in water. The reason that the calcium sulphate stimulates corrosion may be due to the ionization of its sulphuric acid content. Calcium sulphate ionizes very readily in the presence of moisture and evidently stimulates corrosion to a great extent. In fact all the steel plates on the test fence which were painted with calcium sulphate, have become brown all over from the rust that is taking place. The reason no corrosion seems evident on the plates painted with black pigments may be due to the fact that black is very deceptive and the inspector cannot see through to the surface; but I think that if the film of paint was to be removed, corrosion would be seen underneath on the plate in some cases.

MR. THOMPSON.—If these tests taken alone condemn any particular pigment they are, to my mind, unwise tests. I mean Mr. Thompson.

Mr. Thompson. by that merely that the value of the tests will be determined by the painting tests. Now it may readily be found later that a certain pigment in small amount may be stimulative, and that in larger amount it may be in an entirely different class. The object of these painting tests is to determine whether the test which I suggested originally agrees with the exposure tests; in other words, whether a pigment which shows itself to be an accelerator of corrosion in water, will show itself to be an accelerator of corrosion in linseed oil. If the results of the tests in linseed oil do not correspond with the tests in water, then the test falls down. There is no question about that. No conclusions should be drawn now. We may start off with an hypothesis, but it is only a working hypothesis to lead us on to new fields.

Mr. Voorhees. **MR. VOORHEES.**—I believe that we are going too fast in the use of the terms “accelerators and inhibitors.” The test was made under purely laboratory conditions, and the connection between the results obtained with the pigment in water suspension and when applied as an oil film has not been entirely established. The exposure tests that we have under consideration are being carried on so as to connect theory with practice. One aim of the Committee has been to develop accelerated tests which would be in harmony with service; for unless accelerated tests are in harmony with service tests they have no value. I think that we must fully establish the fact that a pigment which has a corroding action on metal when suspended in water has a similar action when it is applied in an oil film as a paint. This is one of the problems which we hope the Committee will investigate during the year.

Mr. Lane. **MR. F. A. LANE.**—Two years ago I started a number of tests on steel plates. It was just before this agitation concerning accelerators and inhibitors. You may be interested to learn that two of the accelerators that have been shown to act in conjunction with one another in equal parts, in a vehicle composed of 90 per cent. of linseed oil and other materials, showed the best results in withstanding oxidation. We have had no indication of corrosion for two years and three months; therefore, it goes to show that a pigment may be an accelerator in water, but in a proper vehicle it may be the direct opposite. I refer to a lead compound and lampblack, giving a bluish-black coating, exceedingly dense in

color, with a thin film, covering 1,000 sq. ft. per gallon under **Mr. Lane.** repeated tests on very large surfaces.

MR. GARDNER.—I do not think that these experiments have **Mr. Gardner.** proceeded to such an extent that they are of much value as yet. Lampblack in oil forms a fairly good excluding coat. This excluding action is good for sometimes three years, and no corrosion may take place during that time; but finally, when the paint film breaks down, corrosion proceeds to a greater extent than before. Black pigments are often good excluders but not good inhibitors. I think it will be two years before Mr. Lane will get practical results from his experiments.

MR. R. S. PERRY.—Mr. Walker referred to two blues, one **Mr. Perry.** of which was a stimulator and the other an inhibitor; yet chemical analyses failed to find any difference between them. I made those two blues, and they were made purposely to determine whether they would support Mr. Thompson's work. Those two blues that were subjected to Mr. Thompson's test analyzed exactly alike. The one was purposely made in the presence of a soluble rust stimulative; the other was purposely made in the absence of anything known as a rust stimulative. A chemist cannot detect by any difference in the analyses of those two blues the conditions under which they were made, but in their effect on iron they exactly support, in a practical field test, the past results of the laboratory work of Mr. Thompson.

REPORT OF COMMITTEE F ON HEAT TREATMENT OF IRON AND STEEL.

INTRODUCTORY STATEMENT BY THE CHAIRMAN OF THE COMMITTEE.

It is not quite clear that the Committee is expected to prepare specifications for annealing, or that such specifications are in themselves needed or desirable. They are therefore presented tentatively, without recommendation as to their adoption. It is for the Society to decide, as a matter of general policy, whether the adoption of any specifications on this subject is wise. Different manufacturers follow different methods of annealing, and it would probably be very difficult to compel all makers to follow these or any other set of directions. Indeed, many makers of steel castings would refuse either to disclose or to discuss their annealing procedure.

The aim in preparing these specifications has been to draw up something which would be of use, first to those who are not already very skillful in such matters, and second as standards to which practice might be referred in case of dispute as to whether a given treatment was reasonable or not. Though skillful steel workers may follow methods more refined than those which we here offer, yet such methods may be less suitable than ours for the particular purposes here in mind.

REPORT.

The Committee on Heat Treatment respectfully recommends the following methods of annealing normal carbon steel, containing not more than 0.90 per cent. of carbon, and with the other elements in their usual proportions. All the directions, except that concerning steel castings, refer to the critical points. In case of steel of unusual composition, the Committee advises that the critical points should be specially determined, so that these directions may be modified in accordance with actual determinations. It is to be remembered that, in the slow temperature changes of

industrial annealings, the critical points lie nearer to their true or theoretical position than they do when determined by the usual method of taking heating and cooling curves. That is to say, the actual position of Ac_1 and Ac_3 in practical annealing is slightly below, and that of Ar_1 and Ar_3 is slightly above, the temperatures shown by taking cooling curves. The difference between the practical and the observed temperatures is greater in the case of Ar_1 than in that of the other critical points.

1. *Carbon Steel Castings containing 0.50 per cent. of carbon or less.*—Heat to $1000^{\circ} C.$ ($1832^{\circ} F.$) for twelve hours and cool slowly. The temperature should not at any time rise above $1050^{\circ} C.$ ($1922^{\circ} F.$).

2. *Rolled and Hammered Steel.*—To relieve stress, the effects of cold or cool working, etc., heat to slightly above the absorption point, (Ac_1 , about $730^{\circ} C.$ [$1346^{\circ} F.$]), and cool slowly.

The absorption point may be recognized easily, because as the temperature rises past it the rate of rise is momentarily lessened, i. e., the rise itself is slightly retarded spontaneously, and may even be wholly arrested. If the reduction in rolling or hammering has been great enough, so that the coarsening of the grain at the high temperature to which the steel had been heated prior to such rolling or hammering has been well effaced, then carrying the heating for this annealing operation far above the absorption point not only is not beneficial, but is even slightly harmful, and the harm increases with the distance above the absorption point to which the temperature is raised, and also with the percentage of carbon. In other words, heating needlessly far above the absorption point is much more hurtful to high-carbon than to low-carbon steel.

3. *To Remedy the Effects of Overheating*, as for instance when the metal has for any reason been allowed to cool from a temperature far above the recalescence point, Ar_1 , without simultaneously undergoing substantial reduction of area by rolling, hammering, or equivalent treatment preventive of harm. In order to remove the effects of such undisturbed cooling from an unduly high temperature, the steel should be reheated to slightly above Ac_3 , and cooled slowly. To raise the temperature far above Ac_3 tends to undo the good done by heating to just above Ac_3 . If the steel has been overheated very highly or for a very long time,

then the length of time during which it must be held above Ac_3 should be increased proportionally. This is better than to carry the reheating to a still higher temperature.

4. *How to Recognize the Temperature Ac_3 .*—When the carbon content is between 0.45 and 0.90 per cent., Ac_3 is the temperature at which the steel loses its magnetism. In steels with carbon content less than 0.45 per cent., Ac_3 is above the temperature of the loss of the magnetism. For those steels Ac_3 can be calculated roughly by the formula:

$$\begin{aligned} Ac_3 &= 900^\circ - C \times 200^\circ \text{ in Centigrade degrees.} \\ &= 1652^\circ - C \times 360^\circ \text{ " Fahrenheit " } \end{aligned}$$

In this formula C is the percentage of carbon in the steel. For instance, if the carbon content is 0.30 per cent., then Ac_3 is about $900^\circ - 200^\circ \times 0.30 = 840^\circ \text{ C.}$, or $1652^\circ - 360^\circ \times 0.30 = 1544^\circ \text{ F.}$ This formula indeed applies also to steel with between 0.45 and 0.90 per cent. of carbon.

5. *Condensed List of the Critical Temperatures Referred to.*

The Recalescence, or Ar_1 , about $700^\circ \text{ C. (1292}^\circ \text{ F.)}$ independently of the carbon content.

The Absorption Point, or Ac_1 , about $730^\circ \text{ C. (1346}^\circ \text{ F.)}$ independently of the carbon content.

Ac_3 . For steel containing less than 0.90 per cent. of carbon, Ac_3 can be calculated roughly by the formula

$$\begin{aligned} Ac_3 &= 900^\circ - C \times 200^\circ \text{ in Centigrade degrees.} \\ &= 1652^\circ - C \times 360^\circ \text{ " Fahrenheit. " } \end{aligned}$$

in which C = the percentage of carbon.

In case of steels containing between 0.45 and 0.90 per cent. of carbon, Ac_3 corresponds to the loss of magnetism on heating.

Respectfully submitted on behalf of the Committee,

HENRY M. HOWE,
Chairman.

DISCUSSION.

MR. J. M. DARKE (by letter).—In connection with the report of Committee F, the results of some experiments along this line made about a year ago may be of interest to others.

In nearly all manufacturing plants, annealing oven space is at a premium, and it therefore becomes desirable to know in how short a time good annealing can be done. In order to determine this point a block of steel 10 ins. long, 6 ins. wide, and 4 ins. deep, was cast of acid open hearth steel of the following composition:

Carbon	0.24	per cent.
Manganese	0.612	" "
Silicon	0.223	" "
Phosphorus	0.057	" "
Sulphur	0.007	" "

Forty-eight test bars were rough machined from this block of steel and given different heat treatments before the final machining operations were performed, as follows:

5 bars unannealed.	
5 bars annealed at 800° C. for 6 hours.	
5 " " " 800° C. " 12 "	
5 " " " 850° C. " 6 "	
5 " " " 850° C. " 12 "	
5 " " " 900° C. " 6 "	
5 " " " 900° C. " 12 "	
4 " " " 1000° C. " 6 "	
4 " " " 1000° C. " 12 "	
5 " " " 850° C. " 6 "	(Experiment repeated.)

A record of the decrease in size of test bars due to formation of scale at the different temperatures was kept and is given below:

Treatment.	Decrease, in inches.
800° C. for 6 hours	none
800° C. " 12 "	0.008
850° C. " 6 "	none
850° C. " 12 "	0.010
900° C. " 6 "	0.003
900° C. " 12 "	0.014
1000° C. " 6 "	not determined.
1000° C. " 12 "	0.037

Mr. Darke. The bars after final machining to a standard 2-in. test bar were broken in a 30,000-lb. Olsen tensile testing machine, with the results shown in Table I, averages only being given.

It is quite evident from these experiments that a satisfactory annealing practice is 850° C. for 6 hours.

When a temperature as high as 1000° C. is employed, it becomes quite a problem to support large shapes in such a manner that they will not become permanently deformed. In the practical operation of an annealing furnace, castings are piled one on another, thus increasing the liability of warping or changing shape due to the plastic condition of the steel at high temperatures.

TABLE I.

Treatment.	Yield Point, lbs. per sq. in.	Tensile Strength, lbs. per sq. in.	Elongation, per cent. in 2 ins.	Reduction in Area, per cent.
Unannealed	30,755	66,010	16.9	19.45
800° C. for 6 hrs. . . .	31,840	68,530	29.3	46.87
800° C. " 12 " . . .	38,691	69,374	26.6	41.60
850° C. " 6 " . . .	41,306	68,868	26.75	41.73
850° C. " 12 " . . .	38,499	67,025	25.1	42.06
900° C. " 6 " . . .	37,913	66,167	29.5	52.70
900° C. " 12 " . . .	35,145	66,501	26.37	46.97
1000° C. " 6 " . . .	37,081	71,625	24.8	37.18
1000° C. " 12 " . . .	36,687	71,800	26.9	32.24
850° C. " 6 "* . . .	41,560	71,600	28.40	47.46

The formation of scale in large amounts is objectionable, and it is obvious that at the higher temperature more scale will be formed. The furnace used in these experiments is an electrically heated muffle, entirely sealed up while the bars were heating, so the formation of scale is considerably less than would occur in a direct-fired furnace. The test bars were allowed to cool in the furnace until they were black. The temperatures were measured with a Le Chatelier element, connected to a Leeds & Northrup reflecting galvanometer.

* The average of the five bars annealed at 850° C. for six hours was so high that the experiment was repeated with practically the same result.

REPORT OF COMMITTEE H ON STANDARD TESTS FOR ROAD MATERIALS.

Your Committee on Standard Tests for Road Materials has made considerable progress during the past year. After careful consideration, the method for the determination of bitumen in asphalt paving mixtures, refined asphalts and asphalt cements, which was reported and accepted by the Society in 1906, has been revised so as to include all bituminous paving and road material. It is believed that this revision can be made without a further investigation by the examination of various samples by members of the Committee and other analysts, as was done before the presentation in 1906 of the method referred to above.

The Committee, in presenting this method of analysis, wish it understood that they do not recommend it as the best for general use, as it is longer and in several cases gives no better results than other more expeditious methods, but only as a method to be resorted to in case of dispute. A rapid method, which is suggested for general use, is also given.

The Committee further recommends the methods for sizing and separating the aggregate in asphalt paving mixtures and determining the consistency of bitumens by penetration, as reported to the Society in 1906 and published in the Proceedings for that year.

Methods for the determination of the loss on heating of oil and asphaltic compounds, and the determination of residual coke in bitumens, are herewith submitted to the Society for the first time.

All of the tests for bituminous compounds for roads and pavements referred to above follow as an appendix to this report.

Respectfully submitted on behalf of the Committee,

PRÉVOST HUBBARD,

Secretary.

LOGAN WALLER PAGE,
Chairman.

APPENDIX.

PROPOSED TESTS FOR BITUMINOUS COMPOUNDS FOR ROADS AND PAVE- MENTS, INCLUDING METHOD OF SIZING AND SEPARATING THE AGGREGATE IN ASPHALT PAVING MIXTURES.*

METHOD FOR THE DETERMINATION OF BITUMEN IN PAVING
COMPOUNDS, INCLUDING THE DETERMINATION OF BITUMEN
IN ASPHALT PAVING MIXTURES, REFINED ASPHALTS,
ASPHALT CEMENTS, BITUMEN-TREATED ROAD
MATERIALS, TARS AND TAR PITCHES,
SOLUBLE IN COLD CARBON DISUL-
PHIDE AND OTHER SOLVENTS.

Drying the Sample and Preparing It for Analysis.—It was decided, owing to the great variety of conditions met with in bituminous compounds, that it is impossible to specify any one method of drying that would be satisfactory in every case. It is therefore supposed that the material for analysis has been previously dried, either in the laboratory or in the process of refining or manufacture, and that water, if present, exists only as moisture in the hygroscopic form.

The material to be analyzed, if hard and brittle, is ground and spread in a thin layer in a suitable dish (iron or nickel will answer every purpose) and kept at a temperature of 125° C. for one hour. In the case of paving mixtures and road materials, where it is not desirable to crush the rock or sand grains, a lump may be placed in the drying oven until it is thoroughly heated through, when it can be crushed down into a thin layer and dried as above. If the material under examination contains any hydrocarbons at all

* These tests are recommended by Committee H, but the Committee is not yet prepared to advise their adoption as "standards" by the Society.

volatile at this temperature, it will of course be necessary to resort to other means of drying.

Analysis of Sample.—After drying, from 2 to 15 grams (depending on the richness in bitumen of the substance) is weighed into a 150-c.c. Erlenmeyer flask, the tare of which has been previously ascertained, and treated with 100 c.c. of carbon disulphide. The flask is then loosely corked and shaken from time to time until practically all large particles of the material have been broken up, when it is set aside and not disturbed for 48 hours. The solution is then decanted off into a similar flask that has been previously weighed, as much of the solvent being poured off as possible without disturbing the residue. The first flask is again treated with fresh carbon disulphide and shaken as before, when it is put away with the second flask and not disturbed for 48 hours.

At the end of this time the contents of the two flasks are carefully decanted off upon a weighed Gooch crucible fitted with an asbestos filter, the contents of the second flask being passed through the filter first. The asbestos filter shall be made of ignited long-fiber amphibole, packed in the bottom of a Gooch crucible to the depth of not over $\frac{1}{8}$ in. After passing the contents of both flasks through the filter, the two residues are shaken with more fresh carbon disulphide and set aside for 24 hours without disturbing, or until it is seen that a good subsidation has taken place, when the solvent is again decanted off upon the filter. This washing is continued until the filtrate or washings are practically colorless.

The crucible and both flasks are then dried at 125° C. and weighed. The filtrate containing the bitumen is evaporated, the bituminous residue burned, and the weight of the ash thus obtained added to that of the residue in the two flasks and the crucible. The sum of these weights deducted from the weight of substance taken gives the weight of bitumen extracted. In the analysis of hard asphalts or tar pitch for their solubility in carbon disulphide and also in the analysis of any of the bitumens for their solubility in naphtha, it is recommended that from 15 to 20 grams of glass beads be introduced into the first flask with the substance. When the flask is shaken, these beads grind up any lump of hard bitumen and thus greatly facilitate the solution of the soluble

constituents. In filtering these solutions through the Gooch crucible, they should be allowed to run through by gravity, as the application of an exhaust appears to cause a clogging of the filtering medium.

This test shall be carried on at a temperature of from 20° to 25° C. When carbon disulphide or carbon tetrachloride are used as solvents, they must be chemically pure. When naphtha is employed, the Committee recommends that in all cases it be described by stating its specific gravity and the temperatures between which it distills.

RAPID METHOD FOR THE DETERMINATION OF MATERIAL IN BITUMINOUS ROAD COMPOUNDS INSOLUBLE IN COLD CARBON DISULPHIDE.

For rapid work the Committee suggests the following method as a convenient one to be employed. It is based in general upon the standard method, and is applicable to practically all bituminous compounds.

From 1 to 10 grams of the water-free material (depending upon the amount of bitumen present) is weighed into a 150-c.c. Erlenmeyer flask, the tare of which has been previously ascertained, and treated with 100 c.c. of carbon disulphide. The flask is then loosely corked and shaken from time to time until practically all large particles of the material have been broken up, when it is set aside for not less than 15 hours. At the end of this time the contents of the flask are decanted off upon a weighed Gooch crucible fitted with a long-fiber amphibole asbestos filter. The residue remaining in the flask is then washed with 50 c.c. of carbon disulphide, allowed to settle, and decanted as before, the insoluble matter being finally brought upon the filter and washed with 100 c.c. of carbon disulphide, or until the washings are practically colorless. The filter and contents are then dried at 125° C., cooled, and weighed. Should any residue remain in the flask, it is also dried and weighed and this weight added to that of the residue in the crucible. The filtrate should be burned off and ignited to an ash and the weight of the ash thus obtained added to that of the insoluble residue. The weight of the total residue deducted from that of the original material gives the weight of bitumen soluble in cold carbon disulphide. In case of tars and pitches the percentage of

insoluble residue, determined as above, minus that of any ash which may be found by igniting a separate sample, is reported as free carbon. Glass beads may be employed in the flask, as described in the standard method for the determination of bitumen. This test shall be carried on at a temperature of from 20° to 25° C.

METHOD FOR THE DETERMINATION OF THE CONSISTENCY OF BITUMEN.

The consistency, or penetration, of a bitumen shall be the distance, expressed in hundredths of a centimeter, that a No. 2 needle will penetrate into it at 25° C. (77° F.), in 5 seconds of time, under a weight of 100 grams, the needle to penetrate direct without friction.

METHOD FOR THE DETERMINATION OF THE LOSS ON HEATING OF OIL AND ASPHALTIC COMPOUNDS.

The loss on heating of oil and asphaltic compounds shall be determined in the following manner: Fifty grams of the water-free material shall be placed in a circular tin box with vertical sides, measuring about 1 in. in depth by $2\frac{3}{8}$ ins. in diameter, internal measurement. The penetration of the material to be examined shall, if possible, be determined at 25° C., in the manner heretofore described, and the exact weight of the sample ascertained. The sample in the tin box shall then be placed in a hot air oven, heated to 170° C., and kept at this temperature for 5 hours. At no time shall the temperature of this oven vary more than 2° C. from 170° C. When the sample is cooled to normal temperature, it shall be weighed and the percentage of loss by volatilization reported. The penetration of the residue shall then, if possible, be determined at 25° C., in the manner heretofore described, and the loss in penetration determined by subtracting this penetration from the penetration before heating.

METHOD FOR THE DETERMINATION OF RESIDUAL COKE IN BITUMINOUS COMPOUNDS.

This determination shall be made according to the method described for coal in the Journal of the American Chemical Society, 1899, Vol. 21, page 1116. The method is as follows: Place

1 gram of pure bitumen, free from water, in a "platinum crucible weighing 20 to 30 grams and having a tightly fitting cover. Heat over the full flame of a Bunsen burner for 7 minutes. The crucible should be supported on a platinum triangle with the bottom 6 to 8 cms. above the top of the burner. The flame should be fully 20 cms. high when burning free, and the determination should be made in a place free from draughts. The upper surface of the cover should burn clear, but the under surface should remain covered with carbon."

The residue minus the small impurity of ash in the pure bitumen is the fixed carbon, which should be calculated to 100 per cent. with the volatile hydrocarbons, excluding the inorganic matter.

METHOD OF SIZING AND SEPARATING THE AGGREGATE IN ASPHALT PAVING MIXTURES.

The method consists of passing the mineral aggregate through several sieves of the following sizes:

	Diameter, in inches.					
10 meshes per linear inch, size of wire		0.027				
20 " " " " " "		0.0165				
30 " " " " " "		0.01375				
40 " " " " " "		0.01025				
50 " " " " " "		0.009				
80 " " " " " "		0.00575				
100 " " " " " "		0.0045				
200 " " " " " "		0.00235				

REPORT OF COMMITTEE I ON REINFORCED CONCRETE.

The Committee on Reinforced Concrete desires to present herewith the report of the Joint Committee on Concrete and Reinforced Concrete, as adopted by letter ballot of the Committee on December 20, 1908. As this report states, the Committee is not able to present a final report at this time and submits this progress report for the information of the members of the several societies represented on the Joint Committee.

It is expected that the Joint Committee will present a final report when sufficient data have been obtained to serve as a basis for final conclusions, and in the meanwhile this report is submitted as the expression of opinion of the majority of the members of the Joint Committee.

Respectfully submitted on behalf of the Committee,

RICHARD L. HUMPHREY,
Secretary.

F. E. TURNEAURE,
Chairman.

PROGRESS REPORT OF THE JOINT COMMITTEE ON CONCRETE AND REINFORCED CONCRETE.

I. INTRODUCTION.

Special committees were appointed by the American Society of Civil Engineers, American Society for Testing Materials, American Railway Engineering and Maintenance of Way Association, and the Association of American Portland Cement Manufacturers, for the purpose of investigating current practice and providing definite information concerning the properties of concrete and reinforced concrete and to recommend necessary factors and formulas required in the design of structures in which this material is used.

At the annual convention of the American Society of Civil Engineers held at Asheville, N. C., June 11, 1903, the following resolution was adopted:

It is the sense of this meeting that a special committee be appointed to take up the question of concrete and steel concrete, and that such committee cooperate with the American Society for Testing Materials and the American Railway Engineering and Maintenance of Way Association.

Following the adoption of this resolution, a special committee on concrete and steel concrete was appointed by the Board of Direction on May 31, 1904. At the annual meeting, held January 18, 1905, the title of this special committee was, at the request of the committee, changed to "Special Committee on Concrete and Reinforced Concrete."

At the annual meeting of the American Society for Testing Materials held July 1, 1903, at the Delaware Water Gap, the following resolution was unanimously adopted:

That the Executive Committee be requested to consider the desirability of appointing a committee on "Reinforced Concrete," with a view of cooperating with the committees of other societies in the study of the subject.

At the meeting of the Executive Committee of this Society, held December 5, 1903, a special committee on "Reinforced Concrete" was appointed.

The American Railway Engineering and Maintenance of Way Association appointed a Committee on Masonry on July 20, 1899, with instructions as a part of its duties to prepare specifications for concrete masonry. A preliminary set of specifications for Portland cement concrete was reported to and adopted by the Association on March 19, 1903. At the meeting held in Chicago on March 17, 1904, the Committee on Masonry was authorized to cooperate with the special committee on Concrete and Reinforced Concrete of the American Society of Civil Engineers, and following this action a special sub-committee was appointed.

At a meeting of the several special committees representing the above mentioned Societies, held at Atlantic City, N. J., June 17, 1904, arrangements were completed for collaborating the work of these several committees through the formation of the Joint Committee on Concrete and Reinforced Concrete. Mr. C. C. Schneider was elected temporary chairman and Prof. A. N. Talbot was elected temporary secretary. The proposed plan of action of the special committee of the American Society of Civil Engineers was outlined, involving the appointment of sub-committees on Plan and Scope, on Tests, and on Ways and Means.

Mr. Schneider and Mr. Schaub, as Chairman and Secretary of the special committee of the American Society of Civil Engineers, were elected permanent Chairman and Secretary of the Joint Committee on Concrete and Reinforced Concrete. Mr. Emil Swensson was elected Vice-Chairman and on the resignation of Mr. Schaub, Mr. Richard L. Humphrey was elected Secretary.

The following is the complete organization of the Joint Committee:

OFFICERS.

Chairman—C. C. SCHNEIDER.

Vice-Chairman—EMIL SWENSSON.

Secretary—RICHARD L. HUMPHREY.

MEMBERS.

American Society of Civil Engineers (Special Committee on Concrete and Reinforced Concrete):

- Greiner, J. E., consulting engineer, Baltimore and Ohio Railroad, Baltimore, Md.
Hatt, W. K., professor of civil engineering, Purdue University, Lafayette, Ind.
Hoff, Olaf, vice-president, Butler Brothers, Hoff and Company, New York, N. Y.
Humphrey, Richard L., consulting engineer, engineer in charge, structural materials testing laboratories, U. S. Geological Survey, Philadelphia, Pa.
Lesley, R. W., president, American Cement Company, Philadelphia, Pa.
Schaub, J. W., consulting engineer, Chicago, Ill.
Schneider, C. C., consulting engineer, Philadelphia, Pa.
Swensson, Emil, consulting engineer, Pittsburg, Pa.
Talbot, A. N., professor of municipal and sanitary engineering, in charge of theoretical and applied mechanics, University of Illinois, Urbana, Ill.
Worcester, J. R., consulting engineer, Boston, Mass.

American Society for Testing Materials (Committee on Reinforced Concrete):

- Fuller, William B., consulting engineer, New York, N. Y.
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The report, herein presented, embodies the present judgment
of the Committee concerning the proper use of concrete and
reinforced concrete.

II. ADAPTABILITY OF CONCRETE AND REINFORCED CONCRETE.

The adaptability of concrete and reinforced concrete for
engineering structures, or parts thereof, is now so well established
that it may be considered one of the recognized materials of con-
struction. It has proved to be a satisfactory material, when
properly used, for those purposes for which its qualities make it
particularly suitable.

I. PROPER USE.

Concrete is a material of very low tensile strength and capable of sustaining but very small tensile deformations without rupture; its value as a structural material depends chiefly upon its durability, its fire-resisting qualities, its strength in compression and its relatively low cost. Its strength increases generally with age.

Plain concrete or massive concrete is well adapted for structural forms in which the principal stresses are compressive. These include foundations, dams, retaining walls and other walls, piers, abutments, short columns and, in many cases, arches. In the design of massive concrete, the tensile strength of the material must generally be neglected.

By the use of metal reinforcement to resist the principal tensile stresses, concrete becomes available for general use in a great variety of structures and structural forms. This combination of concrete and metal is particularly advantageous in the beam, where both compression and tension exist; it is also advantageous in the column, where the main stresses are compressive, but where cross-bending may exist. In structures resisting lateral forces it possesses advantages over plain concrete in that it may be so designed as to utilize more fully the strength rather than the weight of the material.

2. IMPROPER USE.

Failures of reinforced concrete structures are usually due to any one or a combination of the following causes: defective design, poor material, and faulty execution.

The defects in a design may be many and various. The computations and assumptions on which they were based may be faulty and contrary to the established principles of statics and mechanics; the unit stresses used may be excessive, or the details of the design defective.

The design of reinforced concrete structures should receive at least the same careful consideration as those of steel, and only engineers with sufficient experience and good judgment should be intrusted with such work.

The computations should include all minor details, which are sometimes of the utmost importance. The design should clearly show the size and position of the reinforcement and should provide for proper connections between the component parts, so that they cannot be displaced. As the connections between reinforced concrete members are frequently a source of weakness, the design should include a detailed study of such connections, accompanied by computations to prove their strength.

The use of high unit stresses, approaching the danger line, is a defect in the design of reinforced concrete structures.

Articulated concrete structures designed in imitation of steel trusses, may be mentioned as illustrating a questionable use of reinforced concrete.

Poor material is sometimes used for the concrete, as well as for the reinforcement. The use of inferior concrete is generally due to a lack of experience of the contractor and his superintendents, or to the absence of proper supervision.

An unsuitable quality of steel for reinforcement is sometimes prescribed in specifications, for the purpose of reducing the cost. For steel structures, a high grade of material is specified, while the steel used for reinforcing concrete is sometimes made of unsuitable, brittle material.

Faulty execution and careless workmanship may generally be attributed to unintelligent or insufficient supervision.

While other engineering structures upon the safety of which human lives depend are generally designed by engineers employed by the owner, and the contracts let on the engineer's design and specifications, in accordance with legitimate practice, reinforced concrete structures are frequently designed by contractors or by engineers commercially interested, and the contract let for a lump sum.

The construction of buildings in large cities is regulated by ordinances or building laws, and the work is inspected by municipal authorities. For reinforced concrete work, however, the limited supervision which municipal inspectors are able to give is not sufficient. Means for more adequate supervision and inspection should, therefore, be provided.

3. RESPONSIBILITY AND SUPERVISION.

The execution of the work should not be separated from the design, since intelligent supervision and successful execution can be expected only when both functions are combined. The engineer who prepares the design and specifications should therefore have the supervision of the execution of the work.

The Committee recommends the following rules for structures of reinforced concrete for the purpose of fixing the responsibility and providing for adequate supervision during construction:

(a) Before work is commenced, complete plans shall be prepared, accompanied by specifications, static computations, and descriptions showing the general arrangement and all details. The static computations shall give the loads assumed separately, such as dead and live loads, wind and impact, if any, and the resulting stresses.

(b) The specifications shall state the qualities of the materials to be used for making the concrete, and the manner in which they are to be proportioned.

(c) The strength which the concrete is expected to attain after a definite period shall be stated in the specifications.

(d) The drawings and specifications shall be signed by the engineer and the contractor.

(e) The approval of plans and specifications by other authorities shall not relieve the engineer nor the contractor of responsibility.

(f) Inspection during construction shall be made by competent inspectors employed by, and under the supervision of, the engineer and shall cover the following:

1. The materials.
2. The correct construction and erection of the forms and the supports.
3. The sizes, shapes and arrangement of the reinforcement.
4. The proportioning, mixing and placing of the concrete.
5. The strength of the concrete by tests of standard test pieces made on the work.
6. Whether the concrete is sufficiently hardened before the forms and supports are removed.

7. Prevention of injury to any part of the structure by and after the removal of the forms.
8. Comparison of dimensions of all parts of the finished structure with the plans.

(g) Load tests on portions of the finished structure shall be made where there is reasonable suspicion that the work has not been properly performed, or that, through influences of some kind, the strength has been impaired. Loading shall be carried to such a point that twice the calculated working stresses in critical parts are reached, and such loads shall cause no permanent deformations. Load tests shall not be made until after 60 days of hardening.

4. DESTRUCTIVE AGENCIES.

(a) *Corrosion of Metal Reinforcement.*—Tests and experience have proved that steel embedded in good concrete will not corrode, no matter whether located above or below fresh or sea water level. If the concrete is porous so as to be readily permeable to water, as where the concrete is laid with a very dry consistency, the metal may be corroded in the presence of moisture.

(b) *Electrolysis.*—There is little accurate information available as to the effect of electrolysis on concrete. The few experiments that are available seem to indicate that concrete may be damaged through the leakage of small electrical currents through the mass, particularly where steel is embedded in the concrete. These experiments are not conclusive, however, and the large numbers of reinforced concrete structures subject to the action of electrolysis in which the metal and concrete are in perfect condition would seem to indicate that the destructive action reported was due to abnormal conditions which do not often occur in practice.

(c) *Sea Water.*—The data available concerning the effect of sea water on concrete or reinforced concrete are inconclusive and limited in amount. There have been no authentic cases reported where the disintegration has proved to be due entirely to sea water. The decomposition that has been reported manifests itself in a number of ways; in some cases the mortar softens and crumbles; in others, a crust forms which in time comes off. It

has been found, however, that where concrete is proportioned in such a way as to secure a maximum density and is mixed thoroughly, it makes an impervious concrete, upon which sea water has apparently little effect. Sea walls have been standing for considerable lengths of time without apparent injury. In many of our harbors where the water has been rendered brackish through the rivers discharging into them, the action that has been reported has been at the water line and was probably due in part to freezing.

(d) *Acids*.—Concrete of first class quality, thoroughly hardened, is affected appreciably only by strong acids which seriously injure other materials. A substance like manure because of the acid in its composition is injurious to green concrete, but after the concrete has thoroughly hardened it satisfactorily resists such action.

(e) *Oils*.—When concrete is properly made and the surface carefully finished and hardened, it resists the action of such oils as petroleum and ordinary engine oils. Certain oils which contain fatty acids appear to produce injurious effects.

(f) *Alkalies*.—The action of alkalies on concrete is problematical. In the reclamation of arid land where the soil is heavily charged with alkaline salts, it has been found that concrete, stone, brick, iron and other materials are injured under certain conditions. It would seem that at the level of the ground water such structures are disintegrated, possibly due in part to the effect of formation of crystals resulting from the alternate wetting and drying of the surface of the concrete at this ground water line. Such destructive action can be prevented by the use of an insulating coating which will prevent this action from taking place.

III. MATERIALS.

A knowledge of the properties of the materials entering into concrete and reinforced concrete is the first essential. The importance of the quality of the materials used cannot be overestimated, and not only the cement but also the aggregates should be subject to such definite requirements and tests as will insure a concrete of the required quality.

I. CEMENT.

There are available for construction purposes Portland, natural, and Puzzolan or slag cements. Only Portland cement is suitable for reinforced concrete.

(a) *Portland Cement* is the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials. It has a definite chemical composition varying within comparatively narrow limits.

Portland cement should be used in reinforced concrete construction and any construction that will be subject to shocks or vibrations or stresses other than direct compression.

(b) *Natural Cement* is the finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to drive off the carbonic acid gas. While the limestone must have a certain composition, this composition may vary in much wider limits than in the case of Portland cement. Natural cement does not develop its strength as quickly nor is it as uniform in composition as Portland cement.

Natural cement may be used in massive masonry where weight rather than strength is the essential feature.

Where economy is the governing factor a comparison may be made between the use of natural cement and a leaner mixture of Portland cement that will develop the same strength.

(c) *Puzzolan or Slag Cement* is the finely pulverized product resulting from grinding a mechanical mixture of granulated basic blast furnace slag and hydrated lime.

Puzzolan cement is not nearly as strong, uniform or reliable as Portland or natural cement, is not extensively used and never in important work; it should be used only for foundation work underground where it is not exposed to air or running water.

(d) *Specifications.*—The cement should meet the requirements of the Standard Specifications for Cement (see Appendix p. 255). A number of societies have been working on methods for testing and specifications for cement. The best practice seems to be represented in the standard methods of testing and specifications for cement which are the result of the joint labors of special committees of the American Society of Civil Engineers,

American Society for Testing Materials, American Railway Engineering and Maintenance of Way Association, American Institute of Architects, and others.

2. AGGREGATES.

Extreme care should be exercised in selecting the aggregates for mortar and concrete, and careful tests made of the materials for the purpose of determining their qualities and the grading necessary to secure maximum density* or a minimum percentage of voids.

(a) *Fine Aggregate* consists of sand, crushed stone, or gravel screenings, passing when dry a screen having $\frac{1}{4}$ -in. diameter holes. It should be preferably of silicious material, clean, coarse, and free from vegetable loam or other deleterious matter.

A gradation of the grain from fine to coarse is generally advantageous.

Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquettes should show a tensile strength of at least 70 per cent. of the strength of 1:3 mortar of the same consistency made with the same cement and standard Ottawa sand.

(b) *Coarse Aggregate* consists of inert material, such as crushed stone, or gravel, which is retained on a screen having $\frac{1}{4}$ -in. diameter holes. The particles should be clean, hard, durable, and free from all deleterious materials. Aggregates containing soft, flat or elongated particles, should be excluded from important structures. A gradation of sizes of the particles is generally advantageous.

The maximum size of the coarse aggregate shall be such that it will not separate from the mortar in laying and will not prevent the concrete from fully surrounding the reinforcement or filling all parts of the forms. Where concrete is used in mass, the size of the coarse aggregate may be such as to pass a 3-in. ring. For reinforced members a size to pass a 1-in. ring, or a smaller size, may be used.

Cinder concrete is not suitable for reinforced concrete struc-

* A convenient coefficient of density is the ratio of the sum of the volumes of materials contained in a unit volume to the total unit volume.

tures, and may be safely used only in mass for very light loads or for fireproofing.

Where cinder concrete is permissible the cinders used as the coarse aggregate should be composed of hard, clean, vitreous clinker, free from sulphides, unburned coal or ashes.

3. WATER.

The water used in mixing concrete should be free from oil, acid, strong alkalies, or vegetable matter.

4. METAL REINFORCEMENT.

The Committee recommends as a suitable material for reinforcement, steel filling the requirements of the specifications adopted by the American Railway Engineering and Maintenance of Way Association (Appendix, p. 255).

For the reinforcement of slabs, small beams, or minor details, or for the prevention of shrinkage cracks where wire or small rods are suitable, material conforming to the requirements of either specification A or B given in the Appendix (p. 257) may be used.

The reinforcement should be free from rust, scale, or coatings of any character which would tend to reduce or destroy the bond.

IV. PREPARATION AND PLACING OF MORTAR AND CONCRETE.

I. PROPORTIONS.

The materials to be used in concrete should be carefully selected, of uniform quality, and proportioned with a view to securing as nearly as possible a maximum density.

(a) *Unit of Measure.*—The unit of measure should be the barrel, which should be taken as containing 3.8 cu. ft. Four bags containing 94 lbs. of cement each should be considered the equivalent of one barrel. Fine and coarse aggregate should be measured separately as loosely thrown into the measuring receptacle.

(b) *Relation of Fine and Coarse Aggregate.*—The fine and coarse aggregate should be used in such relative proportions as will insure maximum density. In unimportant work it is

sufficient to do this by individual judgment, using correspondingly higher proportions of cement; for important work these proportions should be carefully determined by density experiments and the sizing of the fine and coarse aggregates should be uniformly maintained or the proportions changed to meet the varying sizes.

(c) *Relation of Cement and Aggregates.*—For reinforced concrete construction a density proportion based on 1:6 should generally be used; i. e., one part of cement to a total of six parts of fine and coarse aggregates measured separately.

In columns richer mixtures are often required, while for massive masonry or rubble concrete a leaner mixture of 1:9 or even 1:12 may be used. These proportions should be determined by the strength or wearing qualities required in the construction at the critical period of its use. Experienced judgment based on individual observation and tests of similar conditions in similar localities is the best guide as to the proper proportions for any particular case.

2. MIXING.

The ingredients of concrete should be thoroughly mixed to the desired consistency, and the mixing should continue until the cement is uniformly distributed and the mass is uniform in color and homogeneous, since maximum density and therefore greatest strength of a given mixture depends largely on thorough and complete mixing.

(a) *Measuring Ingredients.*—Methods of measurements of the proportions of the various ingredients, including the water, should be used, which will secure separate uniform measurements at all times.

(b) *Machine Mixing.*—When the conditions will permit, a machine mixer of a type which insures the uniform proportioning of the materials throughout the mass should be used, since a more thorough and uniform consistency can be thus obtained.

(c) *Hand Mixing.*—When it is necessary to mix by hand, the mixing should be on a water-tight platform and especial precautions should be taken to turn the materials until they are homogeneous in appearance and color.

(d) *Consistency.*—The materials should be mixed wet enough to produce a concrete of such a consistency as will flow into

the forms and about the metal reinforcement, and which, at the same time, can be conveyed from the mixer to the forms without separation of the coarse aggregate from the mortar.

(e) *Retempering*.—Retempering mortar or concrete, i. e., remixing with water after it has partially set, should not be permitted.

3. PLACING OF CONCRETE.

(a) *Methods*.—Concrete after the addition of water to the mix should be handled rapidly, and in as small masses as is practicable, from the place of mixing to the place of final deposit, and under no circumstances should concrete be used that has partially set before final placing. A slow setting cement should be used when a long time is likely to occur between mixing and final placing.

The concrete should be deposited in such a manner as will permit the most thorough compacting, such as can be obtained by working with a straight shovel or slicing tool kept moving up and down until all the ingredients have settled in their proper place by gravity and the surplus water has been forced to the surface.

In depositing the concrete under water, special care should be exercised to prevent the cement from being floated away, and to prevent the formation of laitance which hardens very slowly and forms a poor surface on which to deposit fresh concrete. Laitance is formed in both still and running water, and should be removed before placing fresh concrete.

Before placing the concrete care should be taken to see that the forms are substantial and thoroughly wetted and the space to be occupied by the concrete free from débris. When the placing of the concrete is suspended, all necessary grooves for joining future work should be made before the concrete has had time to set.

When work is resumed, concrete previously placed should be roughened, thoroughly cleansed for foreign material and laitance, drenched and slushed with a mortar consisting of one part Portland cement and not more than two parts fine aggregate.

The faces of concrete exposed to premature drying should be kept wet for a period of at least 7 days.

(b) *Freezing Weather*.—Concrete for reinforced structures

should not be mixed or deposited at a freezing temperature, unless special precautions are taken to avoid the use of materials containing frost or covered with ice crystals, and to provide means to prevent the concrete from freezing after being placed in position and until it has thoroughly hardened.

(c) *Rubble Concrete*.—Where the concrete is to be deposited in massive work, its value may be improved and its cost materially reduced through the use of clean stones thoroughly embedded in the concrete as near together as is possible and still entirely surrounded by concrete.

V. FORMS.

Forms should be substantial and unyielding, so that the concrete shall conform to the designed dimensions and contours, and should be tight to prevent the leakage of mortar.

The time for removal of forms is one of the most important steps in the erection of a structure of concrete or reinforced concrete. Care should be taken to inspect the concrete and ascertain its hardness before removing the forms.

So many conditions affect the hardening of concrete, that the proper time for the removal of the forms should be decided by some competent and responsible person, especially where the atmospheric conditions are unfavorable.

VI. DETAILS OF CONSTRUCTION.

I. JOINTS.

(a) *Reinforcement*.—Wherever in tension reinforcement it is necessary to splice the reinforcing bars, the length of lap shall be determined on the basis of the safe bond stress and the stress in the bar at the point of splice; or a connection shall be made between the bars of sufficient strength to carry the stress. Splices at points of maximum stress should be avoided. In columns, large bars should be properly butted and spliced; small bars may be treated as indicated for tension reinforcement or their stress may be taken off by being embedded in large masses of concrete. At foundations, bearing plates should be provided for large bars or structural forms.

(b) *Concrete*.—For concrete construction it is desirable to cast the entire structure at one operation, but as this is not always possible, especially in large structures, it is necessary to stop the work at some convenient point. This point should be selected so that the resulting joint may have the least possible effect on the strength of the structure. It is therefore recommended that the joint in columns be made flush with the lower side of the girders; that the joints in girders be at a point midway between supports, but should a beam intersect a girder at this point, the joint should be offset a distance equal to twice the width of the beam; that the joints in the members of a floor system should in general be made at or near the center of the span.

Joints in columns should be perpendicular to the axis of the column, and in girders, beams and floor slabs, perpendicular to the plane of their surfaces.

2. SHRINKAGE.

Girders should never be constructed over freshly formed columns without permitting a period of at least two hours to elapse, thus providing for settlement or shrinkage in the columns. Before resuming work the top of the column should be thoroughly cleansed of foreign matter and laitance. If the concrete in the column has become hard, the top should also be drenched and slushed with a mortar consisting of one part Portland cement and not more than two parts fine aggregate before placing additional concrete.

3. TEMPERATURE CHANGES.

Concrete is sensitive to temperature changes and it is necessary to take this fact into account in designing and erecting concrete structures. In some positions the concrete is subjected to a much greater fluctuation in temperature than in others, and in such cases joints are necessary. The frequency of these joints will depend, first, upon the range of temperature to which concrete will be subjected; second, upon the quantity and position of the reinforcement. These points should be determined and provided for in the design. In massive work, such as retaining walls, abutments, etc., built without reinforcement, joints should be provided, approximately every 50 feet throughout the

length of the structure. To provide against the structures being thrown out of line by unequal settlement, each section of the wall may be tongued and grooved into the adjoining section. To provide against unsightly cracks, due to unequal settlement, a joint should be made at all sharp angles.

4. FIREPROOFING.

The actual fire tests of concrete and reinforced concrete have been limited, but experience, together with the results of tests so far made, indicate that concrete may be safely used for fireproofing purposes. Concrete itself is incombustible and reasonably proof against fire when composed of a silicious sand and a hard coarse aggregate such as igneous rock.

For a fireproof covering these same materials may be used, or clean, hard burned cinders may be substituted for the coarse aggregate.

The low rate of heat conductivity of concrete is one reason for its value for fireproofing. The dehydration of the water of crystallization of concrete probably begins at about 500° F. and is completed at about 900° F., but experience indicates that the volatilization of the water absorbs heat from the surrounding mass, which, together with the resistance of the air cells, tends to increase the heat resistance of the concrete, so that the process of dehydration is very much retarded. The concrete that is actually affected by fire remains in position and affords protection to the concrete beneath it.

It is recommended that in monolithic concrete columns, the concrete to a depth of $1\frac{1}{2}$ ins. be considered as protective covering and not included in the effective section.

The thickness of the protective coating required depends upon the probable duration of a fire which is likely to occur in the structure and should be based on the rate of heat conductivity. The question of the conductivity of concrete is one which requires further study and investigation before a definite rate for different classes of concrete can be fully established. However, for ordinary conditions it is recommended that the metal in girders and columns be protected by a minimum of 2 ins. of concrete; that the metal in beams be protected by a minimum of $1\frac{1}{2}$ ins. of

concrete, and that the metal in floor slabs be protected by a minimum of 1 in. of concrete.

It is recommended that the corners of columns, girders, and beams be beveled or rounded, as a sharp corner is more seriously affected by fire than a round one.

5. WATERPROOFING.

Many expedients have been used to render concrete impervious to water under normal conditions, and also under pressure conditions that exist in reservoirs, dams, and conduits of various kinds. Experience shows, however, that where mortar or concrete is proportioned to obtain the greatest practicable density and is mixed to a rather wet consistency, the resulting mortar or concrete is impervious under ordinary conditions. A concrete of dry consistency is more or less pervious to water, and compounds of various kinds have been mixed with the concrete or applied as a wash to the surface for the purpose of making it water tight. Many of these compounds are of but temporary value, and in time lose their power of imparting impermeability to the concrete.

In the case of subways, long retaining walls, and reservoirs, leakage cracks may be prevented by horizontal and vertical reinforcement, properly proportioned and located, provided the concrete itself is impervious. Such reinforcement distributes the stretch due to contraction or settlement so that the cracks are too minute to permit leakage, or are soon closed by infiltration of silt.

Asphaltic or coal tar preparations applied either as a mastic or as a coating on felt or cloth fabric, are used for waterproofing, and should be proof against injury by liquids or gases.

6. SURFACE FINISH.

Concrete is a material of an individual type and should not be used in imitation of other structural materials. One of the important problems connected with the use of concrete is the character of the finish of exposed surfaces. The finish of the surface should be determined before the concrete is placed, and the work conducted so as to make possible the finish desired. For many forms of construction the natural surface of the concrete is unobjectionable, but frequently the marks of the boards

and the flat, dead surface are displeasing, making some special treatment desirable. A treatment of the surface which removes the film of mortar and brings the coarser particles of the concrete into relief is frequently used to remove the form markings, break the monotonous appearance of the surface, and make it more pleasing. Plastering of surfaces should be avoided, for the other methods of treatment are more reliable and usually much more satisfactory. Plastering, even if carefully applied, is likely to peel off under the action of frost or temperature changes.

VII. DESIGN.

I. MASSIVE CONCRETE.

In the design of massive concrete or plain concrete, no account should be taken of the tensile strength of the material, and sections should usually be so proportioned as to avoid tensile stresses. This will generally be accomplished, in the case of rectangular shapes, if the line of pressure is kept within the middle third of the section, but in very large structures, such as high masonry dams, a more exact analysis may be required. Structures of massive concrete are able to resist unbalanced lateral forces by reason of their weight, hence the element of weight rather than strength often determines the design. A relatively cheap and weak concrete will therefore often be suitable for massive concrete structures. Owing to its low extensibility, the contraction due to hardening and to temperature changes requires special consideration, and except in the case of very massive walls such as dams, it is desirable to provide joints at intervals to localize the effect of such contraction. The spacing of such joints will depend upon the form and dimensions of the structure and its degree of exposure.

Massive concrete may well be used for piers and short columns, in which the ratio of length to least width is relatively small. Under ordinary conditions this ratio should not exceed six, but where the central application of the load is assured a somewhat higher value may safely be used.

Massive concrete is also a suitable material for arches of moderate span where the conditions as to foundations are favorable.

2. REINFORCED CONCRETE.

By the use of metal reinforcement to resist the principal tensile stresses, concrete becomes available for general use in a great variety of structures and structural forms. This combination of concrete and steel is particularly advantageous in the beam, where both compression and tension exist; it is also advantageous in the column where the main stresses are compressive, but where cross-bending may exist. The theory of design will therefore relate mainly to the analysis of beams and columns.

3. GENERAL ASSUMPTIONS.

(a) *Loads*.—The loads or forces to be resisted consist of:

1. *The dead load*, which includes the weight of the structure and fixed loads and forces.
2. *The live load* or the loads and forces which are variable. The dynamic effect of the live load will often require consideration. Any allowance for the dynamic effect is preferably taken into account by adding the desired amount to the live load or to the live load stresses. The working stresses hereinafter recommended are intended to apply to the equivalent static stresses so determined.

In the case of high buildings the live load on columns may be reduced in accordance with the usual practice.

(b) *Lengths of Beams and Columns*.—The span length for beams and slabs shall be taken as the distance from center to center of supports, but shall not be taken to exceed the clear span plus the depth of beam or slab. Brackets shall not be considered as reducing the clear span in the sense here intended.

The length of columns shall be taken as the maximum unsupported length.

(c) *Internal Stresses*.—As a basis for calculations relating to the strength of structures, the following assumptions are recommended:

1. Calculations should be made with reference to working stresses and safe loads rather than with reference to ultimate strength and ultimate loads.

2. A plane section before bending remains plane after bending.
3. The modulus of elasticity of concrete in compression within the usual limits of working stresses, is constant. The distribution of compressive stresses in beams is therefore rectilinear.
4. In calculating the moment of resistance of beams the tensile stresses in the concrete shall be neglected.
5. Perfect adhesion is assumed between concrete and reinforcement. Under compressive stresses the two materials are therefore stressed in proportion to their moduli of elasticity.
6. The ratio of the modulus of elasticity of steel to the modulus of elasticity of concrete may be taken at 15.
7. Initial stress in the reinforcement due to contraction or expansion in the concrete may be neglected.

It is appreciated that the assumptions herein given are not entirely borne out by experimental data. They are given in the interest of simplicity and uniformity, and variations from exact conditions are taken into account in the selection of formulas and working stresses.

For calculations relative to deflections the tensile strength of the concrete should be taken into account. For such calculations, also, a value of 8 to 12 for the ratio of the moduli corresponds more nearly to the actual conditions and may well be used.

4. T-BEAMS.

In beam and slab construction, an effective bond should be provided at the junction of the beam and slab. When the principal slab reinforcement is parallel to the beam, transverse reinforcement should be used extending over the beam and well into the slab.

Where adequate bond between slab and web of beam is provided, the slab may be considered as an integral part of the beam, but its effective width shall be determined by the following rules:

- (a) It shall not exceed one-fourth of the span length of the beam;
- (b) Its overhanging width on either side of the web shall not exceed 4 times the thickness of the slab.

In the design of T-beams acting as continuous beams, due consideration should be given to the compressive stresses at the support.

5. FLOOR SLABS.

Floor slabs should be designed and reinforced as continuous over the supports. If the length of the slab exceeds 1.5 times its width, the entire load should be carried by transverse reinforcement. Square slabs may well be reinforced in both directions.*

The loads carried to beams by slabs which are reinforced in two directions will not be uniformly distributed to the supporting beam and may be assumed to vary in accordance with the ordinates of a triangle. The moments in the beams should be calculated accordingly.

6. CONTINUOUS BEAMS AND SLABS.

When the beam or slab is continuous over its supports, reinforcement should be fully provided at points of negative moment. In computing the positive and negative moments in beams and slabs continuous over several supports, due to uniformly distributed loads, the following rules are recommended:

- (a) That for floor slabs the bending moments at center and at support be taken at $wl^2/12$ for both dead and live loads, where w represents the load per linear foot and l the span length.

*The exact distribution of load on square and rectangular slabs, supported on four sides and reinforced in both directions, cannot readily be determined. The following method of calculation is recognized to be faulty, but it is offered as a tentative method which will give results on the safe side. The distribution of load is first to be determined by the formula

$$r = \frac{l^4}{l^4 + b^4}$$

in which r = proportion of load carried by the transverse reinforcement, l = length and b = breadth of slab. For various ratios of l/b the values of r are as follows:

l/b	r
1.0	0.50
1.1	0.59
1.2	0.67
1.3	0.75
1.4	0.80
1.5	0.83

Using the values above specified, each set of reinforcement is to be calculated in the same manner as slabs having supports on two sides only, but the total amount of reinforcement thus determined may be reduced 25 per cent. by gradually increasing the rod spacing from the third point to the edge of the slab.

- (b) That for beams the bending moments at center and at support for interior spans be taken at $wl^2/12$, and for end spans they be taken at $wl^2/10$ for center and adjoining support, for both dead and live loads.

In the case of beams and slabs continuous for two spans only, or of spans of unusual length, more exact calculations should be made. Special consideration is also required in the case of concentrated loads.

Where beams are reinforced on the compression side, the steel may be assumed to carry its proportion of stress in accordance with the provisions of Article VII, Section 3, cl. 6. In the case of continuous beams, tensile and compressive reinforcement over supports must extend sufficiently beyond the support to develop the requisite bond strength.

7. BOND STRENGTH AND SPACING OF REINFORCEMENT.

Adequate bond strength should be provided in accordance with the formula hereinafter given. Where a portion of the reinforcement is bent up near the end of a beam, the bond stress in the remaining straight reinforcement will be less than is represented by the theoretical formula.

Where high bond resistance is required, the deformed bar is a suitable means of supplying the necessary strength. Adequate bond strength throughout the length of a bar is preferable to end anchorage, but such anchorage may properly be used in special cases. Anchorage furnished by short bends at a right angle is less effective than hooks consisting of turns through 180° .

The lateral spacing of parallel bars should not be less than 2.5 diameters center to center, nor should the distance from the side of the beam to the center of the nearest bar be less than 2 diameters. The clear spacing between two layers of bars should not be less than $\frac{1}{2}$ in.

8. SHEAR AND DIAGONAL TENSION.

Calculations for web resistance shall be made on the basis of maximum shearing stress as determined by the formulas hereinafter given. When the maximum shearing stresses exceed

the value allowed for the concrete alone, web reinforcement must be provided to aid in carrying the diagonal tensile stresses. This web reinforcement may consist of bent bars, or inclined or vertical members attached to or looped about the horizontal reinforcement. Where inclined members are used, the connection to the horizontal reinforcement shall be such as to insure against slip.

Experiments bearing on the design of details of web reinforcement are not yet complete enough to allow more than general and tentative recommendations to be made. It is well established, however, that a very moderate amount of reinforcement, such as is furnished by a few bars bent up at small inclination, increases the strength of a beam against failure by diagonal tension to a considerable degree; and that a sufficient amount of web reinforcement can readily be provided to increase the shearing resistance to a value from three or more times that found when the bars are all horizontal and no web reinforcement is used. The following allowable values for the maximum shearing stress are therefore recommended, based on the working stresses of Article VIII, p. 252:

- (a) For beams with horizontal bars only 40 lbs. per sq. in.
- (b) For beams in which a part of the horizontal reinforcement is used in the form of bent-up bars, arranged with due respect to the shearing stresses, a higher value may be allowed, but not exceeding 60 lbs. per sq. in.
- (c) For beams thoroughly reinforced for shear a value not exceeding 120 lbs. per sq. in.

In the calculation of web reinforcement to provide the strength required under (c) above, the concrete may be counted upon as carrying one-third of the shear. The remainder is to be provided for by means of metal reinforcement consisting of bent bars or stirrups, but preferably both. The requisite amount of such reinforcement may be estimated on the assumption that the entire shear on a section, less the amount assumed to be carried by the concrete, is carried by the reinforcement in a length of beam equal to its depth.

The longitudinal spacing of stirrups or bent rods shall not exceed three-fourths the depth of the beam.

It is important that adequate bond strength be provided to develop fully the assumed strength of all shear reinforcement.

Inasmuch as small deformations in the horizontal reinforcement tends to prevent the formation of diagonal cracks, a beam will be strengthened against diagonal tension failure by so arranging the horizontal reinforcement that the unit stresses at points of large shear shall be relatively low.

9. COLUMNS.

It is recommended that the ratio of unsupported length of column to its least width be limited to 15.

The effective area of the column shall be taken as the area within the protective covering, as defined in Article VI, Section 4, or in the case of hooped columns or columns reinforced with structural shapes it shall be taken as the area within the hooping or structural shapes.

Columns may be reinforced by means of longitudinal bars, by bands or hoops, by bands or hoops together with longitudinal bars, or by structural forms which in themselves are sufficiently rigid to act as columns. The general effect of bands or hoops is to greatly increase the "toughness" of the column and its ultimate strength, but hooping has little effect upon its behavior within the limit of elasticity. It thus renders the concrete a safer and more reliable material and should permit the use of a somewhat higher working stress. The beneficial effects of "toughening" are adequately provided by a moderate amount of hooping, a larger amount serving mainly to increase the ultimate strength and the possible deformation before ultimate failure.

The following recommendations are made for the relative working stresses in the concrete for the several types of columns:

- (a) Columns with longitudinal reinforcement only, the unit stress recommended for axial compression in Article VIII, Section 3.
- (b) Columns with reinforcement of bands or hoops, as hereinafter specified, stresses 20 per cent. higher than given for (a).

- (c) Columns reinforced with not less than 1 per cent. and not more than 4 per cent. of longitudinal bars and with bands or hoops, stresses 45 per cent. higher than given for (a).
- (d) Columns reinforced with structural steel column units which thoroughly encase the concrete core, stresses 45 per cent. higher than given for (a).

In all cases longitudinal reinforcement is assumed to carry its proportion of stress in accordance with Section 3. The hoops or bands are not to be counted upon directly as adding to the strength of the column.

Bars composing longitudinal reinforcement shall be straight and shall have sufficient lateral support to be securely held in place until the concrete has set.

Where bands or hoops are used, the total amount of such reinforcement shall be not less than 1 per cent. of the volume of the column enclosed. The clear spacing of such bands or hoops shall be not greater than one-fourth the diameter of the enclosed column. Adequate means must be provided to hold bands or hoops in place so as to form a column, the core of which shall be straight and well centered.

Bending stresses due to eccentric loads must be provided for by increasing the section until the maximum stress does not exceed the values above specified.

10. REINFORCING FOR SHRINKAGE AND TEMPERATURE STRESSES.

Where large areas of concrete are exposed to atmospheric conditions, the changes of form due to shrinkage (resulting from hardening) and to the action of temperature are such that large cracks will occur in the mass, unless precautions are taken to so distribute the stresses as either to prevent the cracks altogether or to render them very small. The size of the cracks will be directly proportional to the diameter of the reinforcing bars and inversely proportional to the percentage of reinforcement and also to its bond resistance per unit of surface area. To be most effective, therefore, reinforcement should be placed near the exposed surface and well distributed, and a form in reinforcement used which will develop a high bond resistance.

VIII. WORKING STRESSES.

I. GENERAL ASSUMPTIONS.

The following working stresses are recommended for static loads. Proper allowances for vibration and impact are to be added to live loads where necessary to produce an equivalent static load before applying the unit stresses in proportioning parts.

In selecting the permissible working stress to be allowed on concrete, we should be guided by the working stresses usually allowed for other materials of construction, so that all structures of the same class but composed of different materials may have approximately the same degree of safety.

The stresses for concrete are proposed for concrete composed of one part Portland cement and six parts of aggregate, capable of developing an average compressive strength of 2,000 lbs. per sq. in. at 28 days, when tested in cylinders 8 ins. in diameter and 16 ins. long, under laboratory conditions of manufacture and storage, using the same consistency as is used in the field. In considering the factors recommended with relation to this strength, it is to be borne in mind that the strength at 28 days is by no means the ultimate which will be developed at a longer period, and therefore they do not correspond with the real factor of safety. On concretes in which the material of the aggregate is inferior, all stresses should be proportionally reduced, and similar reduction should be made when leaner mixes are to be used. On the other hand, if, with the best quality of aggregates, the richness is increased, an increase may be made in all working stresses proportional to the increase in compressive strength at 28 days, but this increase shall not exceed 25 per cent.

2. BEARING.

When compression is applied to a surface of concrete larger than the loaded area, a stress of 32.5 per cent. of the compressive strength at 28 days, or 650 lbs. per sq. in. on the above described concrete, may be allowed. This pressure is probably unnecessarily low when the ratio of the stressed area to the whole area of the concrete is much below unity, but is recommended for general use rather than a variable unit based upon this ratio.

3. AXIAL COMPRESSION.

For concentric compression on a plain concrete column or pier, the length of which does not exceed 12 diameters, 22.5 per cent. of the compressive strength at 28 days, or 450 lbs. per sq. in. for 2,000-lb. concrete, may be allowed.

For other forms of columns the stresses obtained from the ratios given in Article VII, Section 9, may govern.

4. COMPRESSION IN EXTREME FIBER.

The extreme fiber stress of a beam, calculated on the assumption of a constant modulus of elasticity for concrete under working stresses, may be allowed to reach 32.5 per cent. of the compressive strength at 28 days, or 650 lbs. per sq. in. for 2,000-lb. concrete. Adjacent to the support of continuous beams, stresses 15 per cent. higher may be used.

5. SHEAR AND DIAGONAL TENSION.

Where pure shearing stress occurs, that is, uncombined with compression normal to the shearing surface, and with all tension normal to the shearing plane provided for by reinforcement, a shearing stress of 6 per cent. of the compressive strength at 28 days, or 120 lbs. per sq. in. for 2,000-lb. concrete, may be allowed. Where the shear is combined with an equal compression, as on a section of a column at 45° with the axis, the stress may equal one-half the compressive stress allowed. For ratios of compressive stress to shear intermediate between 0 and 1, proportionate shearing stress shall be used.

In calculations on beams in which diagonal tension is considered to be taken by the concrete, the vertical shearing stresses should not exceed 2 per cent. of the compressive strength at 28 days, or 40 lbs. per sq. in. for 2,000-lb. concrete.

6. BOND.

The bonding stress between concrete and plain reinforcing bars may be assumed at 4 per cent. of the compressive strength at 28 days, or 80 lbs. per sq. in. for 2,000-lb. concrete, and in the case of drawn wire 2 per cent., or 40 lbs. per sq. in. for 2,000-lb. concrete.

7. REINFORCEMENT.

The tensile stress in steel should not exceed 16,000 lbs. per sq. in. The compressive stress in reinforcing steel should not exceed 16,000 lbs. per sq. in., or 15 times the working compressive stress in the concrete.

In structural steel members the working stresses adopted by the American Railway Engineering and Maintenance of Way Association are recommended.

8. MODULUS OF ELASTICITY.

The value of the modulus of elasticity of concrete has a wide range, depending upon the materials used, the age, the range of stresses between which it is considered, as well as other conditions. It is recommended that in all computations it be assumed as one-fifteenth that of steel, as, while not rigorously accurate, this assumption will give safe results.

Respectfully submitted,

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APPENDIX.

I. STANDARD SPECIFICATIONS.

(a.) *Cement.*

The specifications recommended for cement are those adopted by the American Society for Testing Materials, Aug. 15, 1908. These specifications appear in Vol. VIII, pp. 149-164, and are therefore not reprinted here.

(b.) *Metal Reinforcement.*

1. Abstract Embodying Portions Applicable to Concrete Reinforcement

from the

STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL.

ADOPTED MARCH, 1906, by the

AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION.

83. Steel shall be made by the open-hearth process.
 84. The chemical and physical properties shall conform to the following limits:

**Process of
Manufacture.
Schedule of
Requirements.**

Elements Considered.	Structural Steel.	Rivet Steel.
Phosphorus, max. { Basic	0.04 per cent.	0.04 per cent.
{ Acid	0.08 "	0.04 "
Sulphur, maximum.	0.05 "	0.04 "
Ultimate tensile strength.	Desired	Desired
Pounds per square inch.	60,000	50,000
Elong. min., per cent. in 8 ins., Fig. 1.	1,500,000*	1,500,000
	Ult. tensile stre'gth	Ult. tensile stre'gth
Character of Fracture.	Silky	Silky
Cold Bends without Fracture.	180° flat†	180° flat‡

* See paragraph 11. † See paragraphs 12, 13 and 14. ‡ See paragraph 15.

The yield point, as indicated by the drop of beam, shall be recorded in the test reports.

**Allowable
Variations.**

85. If the ultimate strength varies more than 4,000 lbs. from that desired, a retest shall be made on the same gauge, which, to be acceptable, shall be within 5,000 lbs. of the desired ultimate.

**Chemical
Analyses.**

86. Chemical determinations of the percentages of carbon, phosphorus, sulphur, and manganese shall be made by the manufacturer from a test ingot taken at the time of the pouring of each melt of steel, and a correct copy of such analysis shall be furnished to the engineer or his inspector. Check analyses shall be made from finished material, if called for by the purchaser, in which case an excess of 25 per cent. above the required limits will be allowed.

Number of Tests.

92. At least one tensile and one bending test shall be made from each melt of steel as rolled.

Thick Material.

95. Full-sized material for steel 1 in. thick and over, tested as rolled, shall bend cold 180° around a pin, the diameter of which is equal to twice the thickness of the bar, without fracture on the outside of bend.

Finish.

98. Finished material shall be free from injurious seams, flaws, cracks, defective edges or other defects, and have a smooth, uniform and workmanlike finish. Plates 36 ins. in width and under shall have rolled edges.

Stamping.

99. Every finished piece of steel shall have the melt number and the name of the manufacturer stamped or rolled upon it.

**Defective
Material.**

100. Material which, subsequent to the above tests at the mills and its acceptance there, develops weak spots, brittleness, cracks, or other imperfections, or is found to have injurious defects, will be rejected at the shop and shall be replaced by the manufacturer at his own cost.

2. Alternative specifications for metal reinforcement.

A.

1. For wire and rod reinforcements the steel may be manufactured from Bessemer billets (not re-rolled rails), and shall meet the following requirements:

2. *Tensile Tests.*

Tensile strength, not less than 105,000 lbs. per sq. in.

Yield point, not less than 52,500 lbs. per sq. in., nor more than 90 per cent. of the tensile strength.

Elongation in 8 ins. not less than 10 per cent., with the following modifications:

(a) For each increase in diameter of $\frac{1}{8}$ in. above $\frac{3}{4}$ in., a deduction of 1 per cent. shall be made from the specified elongation.

(b) For materials from $\frac{1}{4}$ in. to, but not including $\frac{5}{16}$ in. diameter, the elongation shall be 8 per cent.

For material $\frac{3}{16}$ in. to $\frac{1}{4}$ in., elongation 7 per cent.

For material $\frac{1}{8}$ in. to $\frac{3}{16}$ in., elongation 6 per cent.

For material less than $\frac{1}{8}$ in., elongation 5 per cent.

3. *Bending Tests.*

Test specimens for bending shall be bent cold under the following conditions without fracture on the outside of the bent portion:

Around twice their own diameter:

1 in. diameter, 80°.

$\frac{3}{4}$ in. diameter, 90°.

$\frac{1}{2}$ in. diameter, 110°.

Around their own diameter:

$\frac{1}{4}$ in. diameter, 130°.

$\frac{3}{16}$ in. diameter, 140°.

$\frac{1}{8}$ in. diameter or less, 180°.

B.

Steel wire used for reinforcement should be drawn from bars of basic open-hearth steel of the same quality as that specified for rivet steel.

Test pieces of wire shall bend 180° around their own diameter without fracture.

2. SUGGESTED FORMULAS FOR REINFORCED CONCRETE CONSTRUCTION.

These formulas are based upon the assumptions and principles given in the article on design.

(a.) *Standard Notation.*

1. *Rectangular Beams.*

The following notation is recommended:

f_s	= tensile unit stress in steel.
f_c	= compressive unit stress in concrete.
E_s	= modulus of elasticity of steel.
E_c	= modulus of elasticity of concrete.
n	= $E_s \div E_c$.
M	= moment of resistance, or bending moment in general.
A	= steel area.
b	= breadth of beam.
d	= depth of beam to center of steel.
k	= ratio of depth of neutral axis to effective depth d .
z	= depth of resultant compression below top.
j	= ratio of lever arm of resisting couple to depth d .
jd	= $d - z$ = arm of resisting couple.
p	= steel ratio (not percentage).

2. *T-Beams.*

b	= width of flange.
b'	= width of stem.
t	= thickness of flange.

3. *Beams Reinforced for Compression.*

A'	= area of compressive steel.
p'	= steel ratio for compressive steel.
f'_s	= compressive unit stress in steel.
C	= total compressive stress in concrete.
C'	= total compressive stress in steel.
d'	= depth to center of compressive steel.
z	= depth to resultant of C and C' .

4. *Shear and Bond.*

V = total shear.

v = shearing unit stress.

u = bond stress per unit area of bar.

o = circumference or perimeter of bar.

Σo = sum of the perimeters of all bars.

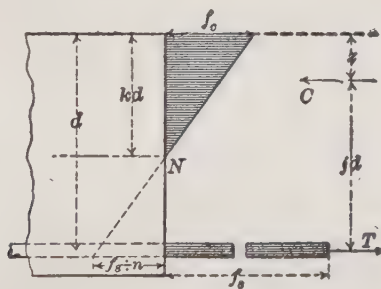
5. *Columns.*

A = total net area.

A_s = area of longitudinal steel.

A_c = area of concrete.

P = total safe load.

(b) *Formulas.*1. *Rectangular Beams.*

Position of neutral axis,

$$k = \sqrt{2pn + (pn)^2} - pn.$$

Arm of resisting couple,

$$j = 1 - \frac{1}{3} k.$$

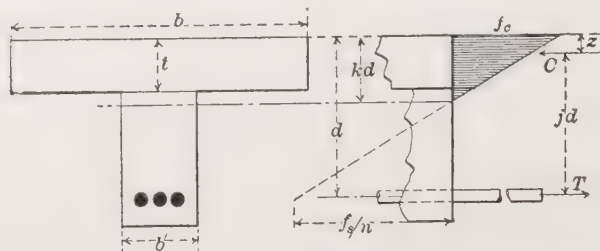
[For $f_s = 15000$ to 16000 and $f_c = 600$ to 650 , k may be taken at $\frac{7}{8}$.]

Fiber stresses,

$$f_s = \frac{M}{Ajd} = \frac{M}{pjb d^2}, \quad f_c = \frac{2M}{jkb d^2} = \frac{2pf_s}{jk}.$$

Steel ratio,

$$p = \frac{1}{2} \cdot \frac{1}{\frac{f_s}{f_c} \left(\frac{f_s}{nf_c} + 1 \right)}.$$

2. *T-Beams.*

Case I. When the neutral axis lies in the flange, use the formulas for rectangular beams.

Case II. When the neutral axis lies in the stem.

The following formulas neglect the compression in the stem:
Position of neutral axis,

$$kd = \frac{2ndA + bt^2}{2nA + 2bt}.$$

Position of resultant compression,

$$z = \frac{3kd - 2t}{2kd - t} \cdot \frac{t}{3}.$$

Arm of resisting couple,

$$jd = d - z.$$

Fiber stresses,

$$f_s = \frac{M}{Ajd}, \quad f_c = \frac{Mkd}{bt(kd - \frac{1}{2}t)jd} = \frac{f_s}{n} \cdot \frac{k}{k - \frac{1}{2}}.$$

(For approximate results the formulas for rectangular beams may be used.)

The following formulas take into account the compression in the stem; they are recommended where the flange is small compared with the stem:

Position of neutral axis,

$$kd = \sqrt{\frac{2ndA + (b - b')t^2}{b'}} + \left(\frac{nA + (b - b')t}{b'} \right)^2 - \frac{nA + (b - b')t}{b'}.$$

Position of resultant compression,

$$z = \frac{(kdt^2 - \frac{2}{3}t^3)b + [(kd-t)^2(t + \frac{1}{3}(kd-t))]b'}{t(2kd-t)b + (kd-t)^2b'}.$$

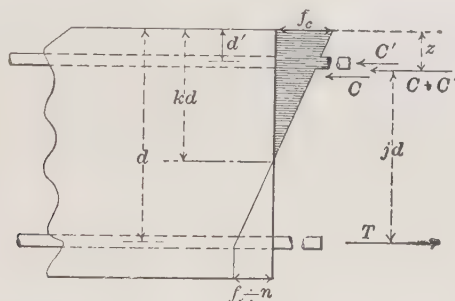
Arm of resisting couple,

$$jd = d - z.$$

Fiber stresses,

$$f_s = \frac{M}{Ajd}, \quad f_c = \frac{2My}{[(2kd-t)bt + (kd-t)^2b']jd}.$$

3. Beams Reinforced for Compression.



Position of neutral axis,

$$k = \sqrt{2n \left(p + p' \frac{d'}{d} \right) + n^2(p + p')^2} - n(p + p').$$

Position of resultant compression,

$$z = - \frac{\frac{1}{3}k^3d + 2p'nd' \left(k - \frac{d'}{d} \right)}{k^2 + 2p'n \left(k - \frac{d'}{d} \right)}.$$

Arm of resisting couple,

$$jd = d - z.$$

Fiber stresses,

$$f_c = \frac{6M}{bd^2 \left[3k - k^2 + \frac{6p'n}{k} \left(k - \frac{d'}{d} \right) \left(1 - \frac{d'}{d} \right) \right]}.$$

$$f_s = \frac{M}{pjbd^2} = nf_o \frac{1-k}{k}.$$

$$f_s' = nf_o \frac{k - \frac{d'}{d}}{k}.$$

4. *Shear, Bond, and Web Reinforcement.*

In the following formulas Σo refers only to the bars constituting the tension reinforcement at the section in question and jd is the lever arm of the resisting couple at the section.

For rectangular beams,

$$v = \frac{V}{bjd}.$$

$$u = \frac{V}{jd \cdot \Sigma o}.$$

[For approximate results j may be taken at $\frac{7}{8}$.]

The stresses in web reinforcement may be estimated by means of the following formulas:

Vertical reinforcement,

$$P = \frac{V_s}{jd}.$$

Reinforcement inclined at 45° ,

$$P = 0.7 \frac{V_s}{jd}.$$

in which P = stress in single reinforcing member, V = proportion of total shear assumed as carried by the reinforcement, and s = horizontal spacing of the reinforcing members.

The same formulas apply to beams reinforced for compression as regards shear and bond stress for tensile steel.

For T-beams,

$$v = \frac{V}{b'jd}, \quad u = \frac{V}{jd \cdot \Sigma o}.$$

[For approximate results j may be taken at $\frac{7}{8}$.]

5. *Columns.*

Total safe load,

$$P = f_o(A_c + nA_s) = f_o A (1 + (n-1)p).$$

Unit stresses,

$$f_o = \frac{P}{A(1 + (n-1)p)}$$

$$f_s = nf_o$$

REPORT OF COMMITTEE K ON STANDARD METHODS OF TESTING.

Your Committee on Standard Methods of Testing respectfully presents the following partial report, which includes recommendations of standard methods of making tensile and compressive tests of metals, and metallographic tests.

The object of the recommendations is to promote accuracy of practice, and uniformity of methods of testing, so that the results obtained from different laboratories will permit of a rational comparison.

These methods are set forth as useful and trustworthy ones, but are not intended as obligatory or to exclude the use of other trustworthy ones, either for original investigators or for industrial laboratories.

Respectfully submitted on behalf of the Committee,

GAETANO LANZA,
Chairman.

METHODS FOR TENSILE TESTS OF METALS.

1. Information obtained from the various laboratories in which tensile tests are made shows that in many cases the forms and dimensions of specimens as recommended by the American Society for Testing Materials are in use, and that in other cases these forms and dimensions most nearly reconcile the differences that exist between the various forms employed.

2. It is therefore recommended that the selection of specimens, and their forms and dimensions, shall conform to the specifications for each material, as are now adopted by the American Society for Testing Materials.

3. It is believed that the distance between the end of gauge length and beginning of shoulders, as prescribed in the standard specifications of the American Society for Testing Materials, is ample to avoid interference with proper elongation, and no grounds are found for recommending any change.

4. All information obtained confirms the investigations of Committee O (since dissolved), to the effect that within the limits of speed common in commercial testing, the effect of different speeds on results is not of observable moment; that is, within ranges of speed varying from 1 to 6 ins. per minute.

5. Beyond these limits, however, very rapid loading influences the ultimate strength, which increases with the speed. Whether the elongation is increased or decreased depends somewhat upon the nature of the material, though in general very rapidly applied loads will increase the stretch, owing to the elongation occurring over the whole body of the specimen, rather than chiefly at the point of reduction, which is more marked with slowly applied loads.

6. Within the limits of speed customary in determining the modulus of elasticity, it does not appear that the rate of loading influences the value obtained, but whether this value be determined by an autographic attachment to the machine, or by an extensometer on the specimen, it is desirable that the loading be not too rapid, or not over 0.05 in. per minute, to avoid impairing the accuracy of the sensitive devices employed.

7. In determining the modulus of elasticity, the elastic limit (the load at which stress and strain are no longer proportional), and the least load producing a given permanent set, it is considered necessary that the extensometer be attached to two sides of the specimen, to compensate for unequal elongation, for improper holding, or for any slight bending that may exist in the specimen.

8. All authorities seem to regard it as desirable to take the stretch on the two sides of the test piece, and most extensometers provide for so doing.

9. The greatest accuracy is required in determining the modulus of elasticity, since small errors in measuring elongation are of considerable consequence in the result.

10. Since the modulus is determined for points well within the elastic limit, the total elongation to be measured is much smaller than at the elastic limit.

11. The elastic limit should be determined with great care, but any inaccuracy will cause less proportionate error than in the case of the modulus. The yield point, being less well defined, cannot be so closely determined, and it is believed that in most

cases the use of dividers instead of an extensometer will give sufficiently accurate results.

12. It is considered undesirable in accurate determinations of the modulus of elasticity to use a shorter gauge length than 8 ins. It is evident that the greater the total elongation measured, the less will be the error due to inaccuracy of the reading, and the accuracy thus appears to increase directly as the gauge length.

13. That the difference between short and long gauge lengths, has a greater influence in affecting results than other factors (personal error, inaccuracy of the testing machine, etc.), is shown by the closely agreeing readings obtained with the greater lengths.

14. The effect of improper methods of holding specimens could not be established from the results of actual tests. The result of improper methods of gripping materials of low stretch, such as cast iron, is well known, and it is probable that in material of a softer nature the effect is largely local and does not extend to the portion of the specimen within the gauge marks.

Conditions to Ensure Correct Testing Machines.—1. It is recommended that in machines on which specimen tests are made, whether the power be applied hydraulically or by means of screws and gears, the load be measured by a separate system of levers and knife edges, or by a method similar to that employed in the Emery testing machines at the Watertown Arsenal.

2. All knife edges shall be kept sharp, and free from oil and dirt, and the machine shall be sensitive to a variation in load of one-two hundred and fiftieth of the load carried. Design and workmanship on testing machines shall be good, and they shall be calibrated at least once every 6 months by the following method:

Calibration of Testing Machines.—1. Test for accuracy by loading the weighing table with standard weights, and compare the actual weight at each addition with the reading of the beam. If the table is uniformly loaded in this manner with the full amount of weights that it will accommodate, the proportionality of the levers and the weighing beam can be successfully established. This relation, in a properly designed machine, will remain constant for all loads, but as a further test for sensitiveness under greater loads than can be accommodated in this manner, the following procedure is recommended.

2. Place in the machine a tension bar of such cross section that the maximum capacity will not stress it to the elastic limit. Stress this bar to various extents through the full range of the machine, and at each load balance the beam and place upon the weighing table standard weights of 100 lbs. A weight one-two hundred and fiftieth of the total load on the machine should produce a readable movement of the beam.

3. Where evidence of the accuracy of the machine over its whole range is desired, a known load may be applied by means of an extensometer and calibrated bar, whose modulus of elasticity has been determined with exactness.

4. It is recommended that a device be adopted conforming to the following requirements, in which the extensometer and bar are permanently attached to each other:

- (a) The bar shall be of high elastic limit material, and of such cross section that this limit will be well above the total capacity of the machine on which it is to be used.
- (b) This bar shall be annealed or otherwise treated so as to eliminate internal or unequal stress in the material, and to ensure its elastic modulus being uniform for successive tests.
- (c) The extensometer shall be permanently attached to the bar, and shall measure the elongation on two opposite sides.
- (d) The extensometer shall be preferably of the indicating or direct reading type, and shall indicate to ten-thousandths of an inch or less.
- (e) The method of securing the bar in the drawheads of the machine shall be positive and without slip, and shall ensure its axial location.
- (f) The length of the bar measured by the extensometer shall be sufficient, that the smallest extensometer division will correspond to a difference in loading of 100 lbs. or less.
- (g) The extensometer shall be protected from injury by a permanently attached case with cover removable for reading the scale.

- (h) The apparatus shall be plainly marked with the maximum load that can be safely applied without injury.
- (i) The apparatus shall itself be calibrated either by the United States Bureau of Standards, or in a manner that will ensure equally trustworthy results.

Methods of Gripping Test Specimens.—1. It is recommended that for specimens of rolled material, serrated grips, flat and V-shaped, be adopted, the former for rectangular and the latter for round specimens. Serrated grips with curved faces appear to have no advantage, and to cause crushing of the material.

2. Wedges with ball and socket do not seem to be necessary, and for commercial testing their use has been generally discontinued.

3. Specimens of turned form, with threaded ends, should be secured in such a manner that side bending stresses are avoided.

4. It is considered important for correct results that the specimen be located in the exact center of the heads, and to better secure this condition, the openings in the heads should be lined up with each other by means of a plumb bob and be tested for parallelism with a spirit level. Each pair of packing pieces and wedges that are to be used together in the same head should correspond exactly in thickness and other dimensions, and the wedges should be inserted an equal distance when the specimen is in place.

Selection and Preparation of Specimen.—1. Specimens representative of steel castings may be cut from the bottom of a sink head or riser, or from a coupon attached to the casting. In either case the part from which the specimen is taken should be relatively large in proportion to the size of the casting and should be annealed with it.

2. Workmanship on specimens shall be of the most careful nature, and surfaces should be free from nicks and tool marks. All wire edges should be removed and corners generously rounded.

3. If specimens of rolled material are sheared in the rough from sections, at least $\frac{1}{8}$ in. of the material should be removed from the sheared edges in machining.

General Requirements for the Measuring of Elongation.—In determining the modulus of elasticity and the elastic limit, it is recommended that when practicable the elongation be measured

in a length not less than 8 ins., and that the following requirements be provided for:

- (a) The specimen shall be round in section, finished as smooth as possible, and shall be provided with threaded ends for attachment to the draw heads of the machine.
- (b) The specimen shall be placed in the exact center of the heads, and be secured in some positive manner, so that slip and side bending stresses do not occur.
- (c) The extensometer should be of a type to measure the elongation on opposite sides of the specimen, and when adjusted the points of attachment should be exactly opposite each other.
- (d) It should read to ten-thousandths of an inch or less.
- (e) It should be of such a design that no change of zero will occur upon release of the load in determining the real elastic limit.
- (f) The load shall be applied so slowly that simultaneous readings of elongation and load can be obtained with certainty.
- (g) The testing machine shall have previously been calibrated for accuracy and sensitiveness, and heads lined up and made parallel.

METHODS FOR COMPRESSIVE TESTS OF METALS.

1. The test specimen shall be a cylinder having plane ends truly normal to its axis.

Only two replies from testing laboratories mention cubes. A cylindrical specimen will usually be cheaper to prepare than a cube. The stresses are probably less uniformly distributed over a square than over a circular section owing to the influence of the corners, this being especially the case with the internal shearing stresses which accompany the compression.

2. The diameter of the specimen shall be not less than 1 in. nor greater than 1.13 ins. A specimen 1 in. in diameter is to be preferred.

The range of diameter mentioned in the replies from testing laboratories is from 1 in. to 1.129 ins. A diameter of 1.1284 ins. gives a section area of one square inch.

3. The length of the specimen should be between 2.5 and 4 diameters.

Two testing laboratories use a length of 1 diameter, one a length of from 1.5 to 2 diameters, one a length of 2.6 diameters, and one a length of 10.5 diameters. It is believed that a length less than 2.5 diameters is not sufficient for the internal shear to be properly developed and that such short lengths give a fictitious strength owing to the friction of the bearing plates of the machine, which causes the specimen to assume a barrel-like form.

4. No bedding should be used for the ends of the specimen.

Only one reply favors bedding. It is known by general experience that bedding modifies the breaking load and that different kinds of bedding have different influences.

5. The bearing blocks which transmit the pressure from the testing machine should be truly normal to the plane ends of the specimen. To secure this, one of the blocks should be provided with a hemispherical bearing which can turn freely.

These requirements seem essential in order that the load may not be eccentrically applied to the specimen, and are generally recommended in the replies from testing laboratories.

6. The speed of compression should be slow, not exceeding 0.1 in. per minute. Near the elastic limit and yield point the load should be increased very slowly.

A lower speed than that stated might be advisable if permitted by the testing machine. Evidently a higher speed may be allowed with a long specimen than with a short one.

7. For determining modulus of elasticity, the linear compression of the specimen should be observed by a precise compressometer which is attached to the specimen and does not touch the bearing blocks of the machine. Readings of the compressometer should be taken for three loads, the first at about one-fourth, the second at about one-half, and the third at about three-fourths of the elastic limit.

It is believed that these measurements are sufficient for most commercial work. Nothing is said about the release of the specimen from load, since opinions differ as to its advisability.

8. To determine the elastic limit, several readings of the compressometer should be taken as that limit is approached for load increments of 1,000 lbs. per sq. in.

This requirement seems sufficient to determine the proportional elastic limit for materials in which such a limit exists. It does not seem wise to require the first permanent set to be observed for ordinary commercial work.

9. The yield point is to be noted as corresponding to that load for which the compressometer shows a linear compression without an increase in load. In the absence of a compressometer this point may be noted, for ductile materials, by the drop of the scale beam.

This requirement corresponds to the usual practice of testing laboratories. It is regarded as important that the term "elastic limit" should not be used to designate the yield point.

10. Measurements for the modulus of elasticity, elastic limit, and yield point may be made, if desired, on a specimen ranging in length from 10 to 15 diameters.

This clause is inserted because it may often be difficult to apply a compressometer in a length shorter than 4 ins.

11. The record of the test should mention any phenomena observed near the elastic limit and yield point. The manner of final failure should also be noted when the test is carried to this limit.

This requirement furnishes data for comparing the behavior of brittle and ductile metals near critical points of molecular change.

METHODS FOR METALLOGRAPHIC TESTS OF METALS.

For general work the following notes are submitted:

Microscopic Examination.—For unhardened iron and steel, the following process has given satisfaction:

1. After polishing, examine under a magnification of 50 to 150 diameters. Look for slag or cinder in wrought iron, manganese sulphide, etc., in steel,* and size and shape of graphite in cast iron.

* Arnold and Waterhouse, *Four. Iron and Steel Inst.*, 1903, I, 136; E. F. Law, *Four. Iron and Steel Inst.*, 1907, II, 94; Fay, *Proc. Am. Soc. Test. Mat.*, 1908, VIII, 74.

2. Etch with a saturated solution of picric acid in alcohol for 15 seconds. This reveals the pearlite* by turning it darker than the accompanying ferrite or cementite. In wrought iron, any pearlite present shows up, and the general appearance will sometimes show whether the material was puddled, etc., or made from reheated scrap. Those who wish to bring out the ferrite grains can do so easily and quickly by etching with nitric acid. To this end, picric acid of 1.42 specific gravity should be diluted with either:

- (a) 90 parts by volume of water to 10 of acid,
- (b) 75 " " " " " " 25 " " or preferably
- (c) 96 " " " " amyl alcohol to 4 of acid.

3. Near the eutectoid point, viz., 0.6 to 1.0 per cent. carbon, it is often difficult to distinguish between thin envelopes of ferrite and cementite. This difficulty can be overcome by etching with a solution of sodium picrate, which turns cementite dark brown or black but does not color the other constituents. The solution is made by adding 2 parts of picric acid to 98 parts of a solution containing 25 per cent. of caustic soda, and is used at 100° C.† In order to interpret the results of such an etching, they should be compared with standard etched specimens.

In the case of hardened and tempered steel the indications are less decisive than in the case of unhardened steel, probably because the former class has been studied less than the latter. Coarse grain, segregation of constituents, presence of oxide, etc., are all signs of bad material. For etching use a solution of 4 per cent. nitric acid, specific gravity 1.42, in 96 of amyl alcohol. The time needed has to be found by trial in each case. Hence etch for 5 seconds, examine, re-etch if necessary,‡ etc.

Macroscopic Examination.—This method shows up defects due to segregation, blowholes, piping, and the like, and when used in connection with microscopic examination yields valuable information. A section is cut with a saw, filed smooth, and polished with No. 0 and No. 00 emery paper; it is then ready for etching.

* Igeevsky, *Rev. de Met.*, II; Lejeune, *Req. de Met.*, III, 426.

† Kourbatoff, *Rev. de Met.*, III, 648.

‡ Kourbatoff, *Rev. de Met.*, III, 648; Lejeune, *Rev. de Met.*, III, 426; Heyn, *Mitt. aus dem König, Materialsprüf, Gross-Lichterfelde, West*, 1906, 29.

Quite a number of etching reagents have been used* to develop the structure. Whichever solution is chosen, the specimen is first carefully washed with a strong caustic potash solution, well rinsed under the tap, and then immersed in the etching solution. The following may be mentioned:

- (a) Freshly prepared solution of 20 grams of I and 30 grams of KI, in 1,000 grams of water.
- (b) Dilute HCl or H_2SO_4 up to 30 per cent. acid, using the 1.2 and 1.84 specific gravity respectively.
- (c) Nitric acid, from 10 to 30 per cent. of the 1.42 specific gravity† acid in 90 to 70 per cent. of water.
- (d) Concentrated HCl, specific gravity 1.2.
- (e) A solution of 10 or 12 parts of double copper-ammonium chloride in 90 or 88 parts of water.

To bring out the structure of wrought iron rapidly, (d) is used, while (c) or (b) will bring it out more slowly.

For steel, first etch with (a), which shows up the segregation of carbon very well. Take care not to over-etch; 5 seconds is enough for some materials. To show up the impurities and the segregation of MnS, slag, etc., (d) acts quickly, but (b) gives better results though taking longer.

Some prefer light etching, say after 1 or 2 minutes, but an older method is to etch with (b) very deeply, indeed to a depth so great that several hours may be needed to reach it. In this way the segregation of the carbon and the impurities like slag and MnS, are shown simultaneously. A picture of the object thus etched can be had by treating it like an engraving, i. e., inking it with printer's ink, and printing on white paper directly from it. A common letter-copying press is convenient for this printing.

*Fremont, *Rev. de Met.*, V, 669. Ast. Internat. Assoc. Test. Materials, 1907. IVth Congress. Problem 2.

† Stead, *Proc. Cleveland Inst. of Engrs.*, Sept., 1906, p. 3.

REPORT OF COMMITTEE L ON STANDARD SPECIFICATIONS AND TESTS FOR CLAY AND CEMENT SEWER PIPES.

The work of the Committee has not for several years been pursued as actively as was hoped and desired. This has been due to the difficulty in obtaining sufficiently authoritative data to permit formulating even preliminary conclusions regarding the strength, durability, and fitness of the materials now used, as well as others more or less untried. The entire subject was found to be in an unsettled state, both here and abroad, due to radical differences of opinion among those who had given the most attention to it. Absence of available funds for original investigations by the Committee has prevented or delayed the securing of information which the Committee has considered essential. All available data have, however, been compiled and during the past two or three years increased interest, both in this country and in Europe, has produced much valuable additional information.

A large number of tests have been conducted by several members of the Committee, and these results are now available for its use. Attention should be called to the fact that the Committee on Standard Specifications for Clay and Cement Pipe of the International Association for Testing Materials has been at work on the subject for a number of years, and has only recently presented a preliminary report regarding certain phases of the subject. The fact that this report was in preparation led your Committee to hope that it might form a basis for the work in America, and it was thought wise to await the results of the European investigation before reaching preliminary conclusions in this country.

During the last twelve months the Chairman, while on a visit in Europe, made personal inquiries and examinations into the subject and consulted with some of the active members of the International Association for Testing Materials. He found interest in some quarters and apathy in others. Among the

interested parties there were, as here, differences of opinion, chiefly due, however, in his opinion, to differences in materials and in their use. He believes that the time has now arrived when useful work in standardizing can be inaugurated in this country with a promise of arriving at practical results.

The Committee of the International Association has done some effective work, and its preliminary and tentative report will be of much service to this Committee.

A recapitulation of the entire subject with reference to American needs and on a broader basis than the aforesaid report, has been made by the Chairman since his return from Europe and will be presented during the coming year to the Committee for discussion, elaboration, verification, or amendment, with the hope that conclusions may soon be reached for a final discussion before the Society.

The subject seems best divided into three classes:

1. The demands made upon sewer pipes.

Under this heading all demands relating both to the materials of vitrified clay and cement and to the usual methods of construction, as well as those relating to the several uses of sewers, should be stated.

2. The practical tests which will secure materials and manufacture that will answer these demands.

Under this heading should be set forth the qualities of the materials, the efficiency of the manufacture, the actual strength and durability of the various materials and combinations of materials used in different parts of the country, and the serviceability both of the completed pipe line and of its elements.

3. Specifications for the work of laying pipe lines under different conditions.

This heading should comprise conclusions regarding transportation and delivery of the pipe to the site of the work, the preparation of the trench and foundations, the laying and joining of the pipes, and the refilling of the trenches, so that the pipes manufactured from the available materials, and laid according to the above conclusions, will furnish in every way a satisfactory and reliable structure.

At this time it is possible to present as a preliminary basis a list of the demands under Class 1. Much information is avail-

able for Classes 2 and 3, and it is the intention to bring the whole matter under discussion during the coming year, and to complete it by making such additional new tests as the Committee may find necessary and practicable.

The demands upon sewer pipes are:

(a) *Strength*.—This includes resistance against rupture, homogeneity of the material, the age of cement pipe before put into use, and the vitrification of clay pipe.

It includes also the necessary data for the thickness of shell, the importance of fire cracks in vitrified pipes and hair cracks in cement pipes.

The proper requirements should be stated for the strength necessary to resist crushing, bursting and impact, under various practical conditions.

(b) *Durability*.—This includes resistance to wear and tear. There should be given the required resistance against abrasion by sand or gravel at high velocities in glazed and unglazed pipes, the density or specific gravity of the material with relation to its porosity and capillary absorption of moisture.

There should be considered the corrosion of glazed and unglazed vitrified clay and Portland cement pipes by acids, alkalies, steam, frost, and gases.

An inquiry should be made into the merits of protective coatings or linings for Portland cement pipes to resist the usual chemical actions of certain ingredients of sewage.

(c) *Serviceability*.—This relates to the efficiency of the pipes to perform the best service.

Under this heading should be considered the question of smoothness, the glazing of vitrified pipes, blisters, the best sectional form for various purposes, and the warping of pipes, including the permissible deviation from true, straight pipes and regular curves or specials.

The best lengths of the individual straight pipes and specials should be determined.

The ends of pipes with reference to making the best joints should receive most careful study to determine the best practice for different conditions, including hub and spigot, butt and collar, and beveled joints.

All specials, such as branches, spurs, curves, etc., should receive attention with reference to recommendations as to size and form.

With the program thus laid out, the Committee is ready to proceed with its work.

Respectfully submitted on behalf of the Committee,

RUDOLPH HERING,
Chairman.

PRELIMINARY REPORT OF COMMITTEE ON STANDARD SPECIFICATIONS FOR COAL.

In carrying out the instructions of the Society, its Executive Committee has authorized and approved a committee of sixty-seven members to consider and report on the subject of specifications for the purchase of coal.

The first meeting of this Committee was held at the Fort Pitt Hotel, Pittsburg, Pa., January 29, 1909. The Committee was there organized by the selection of J. A. Holmes as Chairman, B. F. Bush as Secretary, and with sub-committees to take up the consideration of specifications as applied to the following classes of coals:

- Sub-Committee No. 1, on Coals for Steam Power Plants, W. F. M. Goss, Chairman;
- Sub-Committee No. 2, on Coals for Producer Gas Plants, R. H. Fernald, Chairman;
- Sub-Committee No. 3, on Coals for Domestic and Heating Plants, J. E. Woodwell, Chairman;
- Sub-Committee No. 4, on Metallurgical Coals, C. F. Robinson, Chairman;
- Sub-Committee No. 5, on Coals for Illuminating Gas, Alfred H. White, Chairman;
- Sub-Committee No. 6, on Coals for Cement Drying, Brick Kilns, etc., Edward Orton, Jr., Chairman;
- Sub-Committee No. 7, on Sampling and Testing of Coals, D. T. Randall, Chairman;
- Sub-Committee No. 8, on Forms of Contract in Coal Purchases, S. H. Taylor, Chairman;
- Sub-Committee No. 9, on Educational Work in behalf of more Efficient Mining, Preparation, and Use of Coal, J. A. Holmes, Chairman.

The practicability of adopting specifications for the purchase of the above different classes of coals has been discussed by correspondence among the members of the several sub-committees named above; and the general subject of coal specifications has been discussed individually, by correspondence and

occasional personal interviews between members of the Committee, during the past several months. No forms of specifications have as yet been agreed upon, however, and your Committee at this time can but submit a preliminary statement as a report of progress, and ask to be continued.

The Committee recognizes the growing interest in the general subject of the purchase of materials under specifications, and it is believed that in all cases where a rational basis for such specifications can be agreed upon, the results of such practice must be beneficial to both producer and consumer, as it enables the consumer to point out more specifically just what he wants; it enables the producer to offer bids on a more intelligent basis; and it makes equitable settlements easier.

In any industry, however, the sudden introduction of a system of ill-digested specifications is likely to work hardship, especially on the producer, without compensating benefits even to the consumer. This is especially apt to be true in an industry so large, so little organized, and contending with so many unsettled problems, as the soft coal industry of to-day. Some of the recently promulgated specifications for the purchase of coal show the extremes to which this system may be carried before the difficulties involved are adequately understood.

Thus, one of these recent specifications prescribes that the coals offered for use at a station within easy reach of one of the coal fields should have 15,000 British thermal units and not exceeding 3.25 per cent. ash, 1.00 per cent. sulphur, and 0.90 per cent. moisture. Other specifications have been recently adopted in a number of cases which are equally impracticable and unnecessarily stringent, which prescribe no satisfactory methods of sampling or testing the coals, render premiums impossible and penalties inevitable on coals, the prices of which are already so low as to leave no possibility of profit to the producer except by involving extensive and permanent waste of coal in mining. Still other specifications have been fully as irrational and unfair, because leaving the sampling and testing, and in fact the adjustment of differences, entirely in the hands of one of the interested parties, and based on inadequate tests.

Your Committee desires to emphasize at this time certain reforms which are regarded as fundamental accompaniments or outgrowths of the present movement for specifications, and which

are essential to the welfare of the coal industry in the United States, namely:

1. A classification of coals with respect to fuel efficiency; the adaptation of equipment to coals for obtaining the greatest efficiency from each class of these fuels; the continued use at each plant of that type of fuel best adapted to the equipment; the use of low grade fuels either at or near the mines, and the use of the high grade fuels under conditions demanding highest efficiency and requiring distant transportation.

2. Special efforts on the part of architects and engineers to provide everywhere adequate space for power and heating plants and proper equipment, with a view to making the most efficient use of the fuels that are most available.

3. Such readjustment in the prices at the mines of the different classes of coals as will render possible clean and safe mining, and the use at local or distant points of all grades of coal worthy of being placed on the fuel list.

The realization of these essential reforms will naturally be slow of accomplishment, and to hasten this movement every engineer, and indeed every citizen of the country, should, as a national duty, contribute to the best of his ability.

The Committee deprecates the hasty adoption of extreme specifications such as those mentioned above, for the reason that such action hinders rather than helps this movement, without any compensating benefits to either producer or consumer. At the same time the Committee recognizes the fact that a proper specification should and will, when understood, encourage the use of all grades of fuels; and it should provide, as do some of those now in force, an equitable basis for the adjustment of the differences between producers and consumers.

If continued, your Committee will endeavor to submit for the later consideration of the Society forms of specifications for the several types of coal mentioned above, in so far as the use of such specifications may be considered as helpful to industry, and contributing to the equitable relations between interested parties.

Respectfully submitted on behalf of the Committee,

J. A. HOLMES,
Chairman.

B. F. BUSH,
Secretary.

REPORT OF COMMITTEE P ON FIREPROOFING MATERIALS.

Since no criticisms or suggestions of changes have been received regarding the proposed Standard Test for Fireproof Partition Construction, presented by this Committee to the Society for consideration at the last Annual Meeting, your Committee recommends that the following specifications presented tentatively at that time be referred to letter ballot of the Society.

At a recent meeting of our Committee, it was decided that the Committee would next consider the subject of a proper specification for a fire test of column protective covering, and the Committee would be very pleased to receive information or suggestions on this topic from any of our members.

Respectfully submitted on behalf of the Committee,

IRA H. WOOLSON,
Chairman.

R. P. MILLER,
Secretary.

NOTE.—The Test for Fireproof Partition Construction was adopted by letter ballot of the Society on August 16, 1909, and follows this report.—ED.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD TEST FOR FIREPROOF PARTITION CONSTRUCTION.

ADOPTED AUGUST 16, 1909.

The test structure may be located at any place convenient to the investigator, where all the necessary facilities for properly conducting the test are provided.

The test structure shall be of such design that the partition construction to be tested shall form at least one side of the structure. The other sides, roof, and foundations of the structure may be of any materials and design that will withstand and confine the fire within the test structure for the required time.

At a height of not less than 2 ft. 6 ins., nor more than 3 ft., above the ground level, a metal grate, properly supported, shall be provided, covering the whole inside area of the building.

In the walls below the grate level, draught openings shall be provided, as many as possible, furnishing openings with an aggregate area of not less than one square foot for every ten square feet of grate surface. Means for temporarily closing these openings shall be provided.

Immediately above the grate level, in one of the end walls of the structure, a firing door 3 ft. 6 ins. wide by 5 ft. high must be provided.

Flues shall be supplied at each of the corners, and more often for a test structure with more than 250 sq. ft. of grate surface, with sufficient opening to insure a proper draught. In no case shall a flue area be less than 180 sq. ins.

The size of the test structure will depend on the area of the

partition construction to be tested. In no case shall the partition construction under test be less than 9 ft. 6 ins. high, nor less than 14 ft. 6 ins. long. This entire area must be above the level of the grate bars, and, within such dimensions, must not be reinforced or braced in any manner other than is done as an inherent and essential part of the system of construction. The edges may be supported in any manner fairly representing the conditions of support in good practice.

The width of the test structure at right angles to the partition under test shall not be less than 9 ft.

The construction to be tested shall be subjected for two hours to the continuous heat of a fire, rising in temperature to 1700° F. by the end of the first half hour, and maintained at an average temperature of 1700° F. for the balance of the test; the fuel used being either wood, gas or oil, so introduced as to cause an even distribution of the heat throughout the test structure.

The temperature obtained shall be measured by means of standard pyrometers under the direction of an experienced person. The type of pyrometer is immaterial so long as its accuracy is secured by proper standardization. The temperature should be measured near the center of the test structure about 6 ins. below the roof or ceiling, and also at the center of each partition under test about 7 ft. above the grate level. In case the partition under test is more than 15 ft. long, additional pyrometers shall be used, symmetrically disposed and not more than 12 ft. apart. Temperature readings at each point shall be taken every three minutes, and the average used as the controlling temperature.

At the end of the heat test, a stream of water shall be directed against the construction under test, discharged through a 1½-in. nozzle, under 30 lbs. nozzle pressure, for two and one-half minutes, the nozzle being held within 2 ft. of the firing door and the hose stream being played backward and forward over the entire surface of the partition under test.

The test shall not be regarded as successful unless the following conditions are met: No fire or smoke shall pass through the partition during the fire test; the partition must safely sustain the pressure of the hose stream; the partition must not warp or bulge, or disintegrate under the action of the fire or water to such an extent as to be unsafe.

REPORT OF COMMITTEE Q ON STANDARD SPECIFICATIONS FOR THE GRADING OF STRUCTURAL TIMBER.

During the last two years the Committee has been endeavoring to have the Standard Specifications for Structural Timbers, adopted by the American Society for Testing Materials on September 1, 1907, also adopted by the American Railway Engineering and Maintenance of Way Association and the Southern Yellow Pine Manufacturers' Association. After the adoption of the standard specifications by the American Society for Testing Materials, it was found that, owing to the rapidly changing conditions of the lumber market and the changing engineering requirements, it would be necessary to modify these specifications to some extent. A number of joint meetings were held by the sub-committee of Committee Q of the American Society for Testing Materials, a sub-committee of the Committee on Wooden Bridges and Trestles of the American Railway Engineering and Maintenance of Way Association, and a committee of the Southern Yellow Pine Manufacturers' Association, at which the specifications, as adopted by the American Society for Testing Materials, were presented. As finally worked out, these specifications were adopted in January of this year by the Southern Yellow Pine Manufacturers' Association, and in March of this year by the American Railway Engineering and Maintenance of Way Association.

In order that these specifications may in reality be standard specifications for all structural timbers, your Committee recommends that Article IV of the Standard Specifications for Structural Timber adopted September 1, 1907, on Standard Specifications for Bridge and Trestle Timbers, be amended, and adopted by the Society. The proposed specifications in their amended form are as follows:

IV. STANDARD SPECIFICATIONS FOR BRIDGE AND TRESTLE TIMBERS.

(To be applied to single sticks and not to composite members.)

GENERAL REQUIREMENTS.

Except as noted, all timbers shall be sound, sawed to standard size, square edged and straight; shall be close grained and free from defects, such as injurious ring shakes and cross grain, unsound or loose knots, knots in groups, decay, or other defects that will materially impair its strength.

Standard Size of Sawed Timber.—Rough timbers sawed to standard size shall mean that they shall not be over $\frac{1}{4}$ in. scant from the actual size specified. For instance, a 12 x 12-in. timber shall measure not less than $11\frac{3}{4}$ x $11\frac{3}{4}$ ins.

Standard Dressing of Sawed Timber.—Standard dressing shall mean that not more than $\frac{1}{4}$ in. shall be allowed for dressing each surface. For instance, a 12 x 12-in. timber after being dressed on four sides shall measure not less than $11\frac{1}{2}$ x $11\frac{1}{2}$ ins.

STRINGERS.

Standard Heart Grade. Longleaf Yellow Pine.—Shall show not less than 85 per cent. heart on the girth anywhere in the length of the piece; provided, however, that if the maximum amount of sap is shown on either narrow face of the stringer, the average depth of sap shall not exceed $\frac{1}{2}$ in. Knots greater than $1\frac{1}{2}$ ins. in diameter shall not be permitted at any section within 4 ins. of the edge of the piece; but knots shall in no case exceed 4 ins. in their largest diameter.

Standard Grade. Longleaf and Shortleaf Yellow Pine.—Shall be square cornered, with the exception of 1 in. wane on one corner. Knots shall not exceed in their largest diameter one-fourth the width of the face of the stick in which they occur, and shall in no case exceed 4 ins. Ring shakes shall not extend over one-eighth of the length of the piece.

CAPS AND SILLS.

Standard Heart Grade. Longleaf Yellow Pine.—Shall show not less than 85 per cent. heart on each of the four sides, measured across the sides anywhere in the length of the piece, and shall be free from knots over $2\frac{1}{2}$ ins. in diameter.

Standard Grade. Longleaf and Shortleaf Yellow Pine.—Shall be square cornered, with the exception of 1 in. wane on one corner, or $\frac{1}{2}$ in. wane on two corners. Knots shall not exceed

in their largest diameter one-fourth the width of the face of the stick in which they occur, and shall in no case exceed 4 ins. Ring shakes shall not extend over one-eighth of the length of the piece.

POSTS.

Standard Heart Grade. Longleaf Yellow Pine.—Shall show not less than 75 per cent. heart on each of the four faces, measured across the sides anywhere in the length of the piece, and shall be free from knots over $2\frac{1}{2}$ ins. in diameter.

Standard Grade. Longleaf and Shortleaf Yellow Pine.—Shall be square cornered, with the exception of 1 in. wane on one corner, or $\frac{1}{2}$ in. wane on two corners. Knots must not exceed in their largest diameter one-fourth the width of the face of the stick in which they occur, and shall in no case exceed 4 ins. Ring shakes shall not extend over one-eighth of the length of the piece.

LONGITUDINAL STRUTS AND GIRTS.

Standard Heart Grade. Longleaf Yellow Pine.—One side shall show all heart, and the other side shall show not less than 85 per cent. heart, measured across the side anywhere in the length of the piece; shall be free from any large knots or other defects that will materially injure its strength.

Standard Grade. Longleaf and Shortleaf Yellow Pine.—Shall be square edged and sound, and shall be free from any large knots or other defects that will materially injure its strength.

LONGITUDINAL X-BRACES, SASH BRACES AND SWAY
BRACES.

Standard Heart Grade. Longleaf Yellow Pine.—Shall show four square corners and not less than 80 per cent. heart on each of two faces, and shall be free from any large knots or other defects that will materially injure its strength.

Standard Grade. Longleaf and Shortleaf Yellow Pine.—Shall be square cornered and sound, and shall be free from any large knots or other defects that will materially injure its strength.

TIES AND GUARD RAILS.

Standard Heart Grade. Longleaf Yellow Pine.—Shall show one side all heart; the other side and two edges shall show not

less than 75 per cent. heart, measured across the face anywhere in the length of the piece; shall be free from any large knots or other defects that will materially injure its strength; and where surfaced, the remaining rough face shall show all heart.

PROGRESS REPORT.

In its first report to the American Society for Testing Materials, made at the annual meeting in 1906, Committee Q presented a list of standard names for structural timbers, which was formally adopted by the Society on September 1, 1907. In this list one of the principal timbers considered was "Southern Yellow Pine." The Committee defined Southern yellow pine as follows:

1. *Southern Yellow Pine*.—Under this heading two classes of timber are used, (a) Longleaf Pine, (b) Shortleaf Pine.

It is understood that these two terms are descriptive of quality rather than of botanical species. Thus, shortleaf pine would cover such species as are now known as North Carolina pine, loblolly pine and shortleaf pine. "Longleaf Pine" is descriptive of quality, and if Cuban, shortleaf, or loblolly pine is grown under such conditions that it produces a large percentage of hard summer wood, so as to be equivalent to the wood produced by the true longleaf, it would be covered by the term "Longleaf Pine."

It will be noted that the different classes of Southern yellow pine are distinguished on the basis of "quality," and it was realized at the time that the method of distinguishing pines, as stated in the definition, was vague, but it was the best that could be presented at that time. During the last three years the Committee has been endeavoring to find some method by which the different classes of Southern yellow pine could be distinguished definitely by means of other than botanical differences of the leaves, cones, or bark. In other words, it was the endeavor of the Committee to find some practical method by means of which the average timber inspector, engineer, architect, or contractor, could, with more or less certainty, tell longleaf from shortleaf pine without having recourse to identifying the timbers in the forests.

It has been universally admitted by those most familiar with yellow pine timbers in their manufactured form, that it is prac-

tically impossible to definitely distinguish longleaf from shortleaf, or shortleaf from loblolly pine, or vice versa; i. e., the characteristics of the Southern pines, as far as the quality of their wood is concerned, intergrade so gradually that no definite dividing line can be established, nor have any means yet been found which are definite enough to permit even an approximate method for distinguishing these methods.

The Committee on Wooden Bridges and Trestles of the American Railway Engineering and Maintenance of Way Association has adopted the standard names recommended by Committee Q, with the exception of the names for Southern yellow pines. Their committee recommended the adoption of the terms "longleaf, shortleaf, and loblolly." Objections were made by the members of Committee Q of this Society to the adoption of this classification. At the annual meeting of the American Railway Engineering and Maintenance of Way Association, held in March, 1908, Proceedings, Vol. 9, page 375, the Association did not vote on the classification as recommended by their committee. In Bulletin No. 107 (January, 1909) of the Association, the Committee on Wooden Bridges and Trestles states on page 7:

The report made the previous year on standard names for structural timbers was re-submitted, but at the request of the Committee final action was deferred for another year.

In view of this paragraph in the formal report of the Committee, the members of Committee Q of this Society took no further formal action with reference to this subject.

However, in Bulletin No. 109 (March, 1909) of the American Railway Engineering and Maintenance of Way Association, the Secretary and Chairman of Committee Q presented a discussion with reference to the trade names for the Southern yellow pines, and submitted suggestions of a definite nature for distinguishing the Southern pines. In this discussion it was pointed out that the best experts cannot, with any degree of certainty, distinguish the various botanical species of Southern pines after these have been manufactured into lumber and timbers, and the recommendation was made that for practical purposes the Southern pines be classified into longleaf and shortleaf pines. In order to substantiate the statement that the best "experts" have failed to find a

definite method for distinguishing the Southern pines, the following quotation was presented:

That even the most exact microscopic methods are not always to be depended upon is well shown in a recent publication, "North American Gymnosperms," by Dr. D. P. Penhallow, probably the leading authority on the microscopic character of American woods, who, in applying the key for determining the different species of wood, selected a number of test specimens from both hardwoods and pines. Of this final test he says in the introduction of the volume: "A final application of the test specimens under the precise conditions which would obtain in ordinary practice, showed a verification of 91.5 per cent. for all genera and species. In this connection it may be of interest to note that the greatest sources of error were to be found in the second section of the genus *Pinus* (pines), particularly in *P. taeda* (loblolly pine), *P. echinata* (shortleaf pine), and *P. glabra* (spruce pine), in the order given, whence it appears that these species stand out as the most variable of the entire coniferales (pine family) and, on the whole, the most difficult to determine." The writer has quoted from the volume thus extensively because this quotation, coming as it does from the highest authority in this country, shows better than any lengthy argument that even with the most exact microscopic methods, it is a hazardous thing to try to distinguish pieces of wood of the Southern pines with any degree of certainty and exactness. If this cannot be done microscopically, how can we expect the engineer and timber inspector to classify these timbers by merely looking at them?

At the meeting of the American Railway Engineering and Maintenance of Way Association in March, 1909, the Committee on Wooden Bridges and Trestles recommended the adoption of three groups of Southern yellow pines. No method was given in their report, as finally adopted, which would in any way indicate what the committee means by longleaf, shortleaf, and loblolly.

This historical phase of the matter is presented to show that your Committee has done its best to bring about an investigation which would in some way standardize a much mooted problem.

Committee Q acknowledges the fact that the distinguishing of the various classes of Southern pine is, as conducted at present, in a most unsatisfactory condition. In order to find some definite means for distinguishing these timbers, several suggestions were made, as follows: First, to distinguish them by measuring the relative amount of spring and summer wood in each annual ring; second, to distinguish them by weight; and third, to distinguish

them by counting the number of annual rings per inch. The first two suggestions were dropped, because it was believed that for commercial purposes it would be impracticable to use the refined methods necessary to measure the relative amount of spring and summer wood, and also impracticable to weigh the individual pieces. The third suggestion, namely, to attempt a classification on the basis of the number of annual rings per inch, appeared to give a possible method for separating the various classes of Southern pine.

It should be stated at the outset that the purpose of a classification of this kind is to determine quality and not botanical species. Good timber is to be accepted regardless of the leaves, cones, etc., of the trees. Counting the number of rings per inch would practically mean that the rate of growth is used as a factor for determining the relative value of the timbers. The Committee believed that a certain specified number of rings per inch could be used as a basis for separating the various classes of Southern pines, having in mind that while such a method might be open to objections, it at least is some improvement on the present system. The Committee felt warranted at any rate in having a considerable number of measurements made of yellow pine timbers from various parts of the South, and has drawn up tentative specifications.

In presenting these considerations, the Committee wishes to emphasize strongly that they should be taken as a preliminary step, and the only reason for presenting them at this time is that they may stimulate a wider interest among the users of yellow pine structural timbers, and at the same time call forth general criticism and discussion. It may develop that the suggestions hereinafter made cannot be applied.

Individual pine trees vary considerably as to their rate of growth. The majority of the individuals of the various species of the Southern pine, however, show an increase in the number of rings per inch from the heart outward; i. e., the number of rings per inch in the outer part of the tree is generally greater than near the center of the tree. This will be evident from Table I, furnished by the United States Forest Service.

Any classification on the basis of the number of rings per inch must be formulated in such a way that reference is had as to

TABLE I.—NUMBER OF RINGS PER INCH ON THE STUMP IN LONGLEAF, LOBLOLLY, AND SHORTLEAF PINES IN DIFFERENT LOCALITIES.

Distance from Heart, inches.	Loblolly (<i>Pinus taeda</i>).			Shortleaf (<i>Pinus echinata</i>).			Longleaf (<i>Pinus palustris</i>).			
	Berkeley County, S. C. (1)	Calhoun County, Ark. (2)	Eastern Texas, with thicket hardwoods. (3)	Polk and Monroe Counties, Tenn. (4)	Calhoun County, Ark. (2)	Reynolds County, Mo. (5)	Coosa County, Ala. (6)	Jasper County, Texas. (7)	Berkeley County, S. C. (1)	
1	5	9	5	15	16	12	13	15	14	10
2	4	10	5	13	16	11	12	12	13	11
3	5	10	5	11	16	12	12	12	12	11
4	5	10	6	9	18	12	13	12	11	11
5	5	11	6	10	18	13	15	13	12	11
6	6	11	7	10	22	14	18	13	15	10
7	7	11	7	10	24	14	22	15	17	11
8	8	12	8	10	26	15	26	17	20	15
9	9	12	10	13	31	17	26	18	23	21
10	12	13	..	16	34	19	..	19	28	25
11	12	14	..	..	39	24	..	20	30	27
12	14	14	..	..	40	..	..	25	30	..
13	14	16	..	..	..	..	..	30	30	..
14	15	..	..	..	..	..	..	..	30	..
15	..	..	..	..	..	..	..	..	31	..
Number of Trees Measured.										
	?	673	499	105	?	398	231	265	1292	?

(1) Working Plan, Burton Company, S. C. Chapman, Merrill.

(2) Working Plan, Stout-Greer, Ark. Record.

(3) Loblolly Pine Study, Texas. R. Zon.

(4) Working Plan, Wetmore and Stevenson Lands, Tenn. Olmsted.

(5) Forest Conditions in Missouri. Record.

(6) Working Plan, Kaul Tract, Ala. Reed.

(7) Working Plan, Houston Oil Lands, Texas. Sherrard.

where the measurements are to be made; i. e., whether they are to be made near the heart, or near the sap, or between the two. Another point which has been raised is, that in the rate of growth shortleaf approaches longleaf pine, while loblolly is in a class by itself. A large number of measurements were made of the various groups of yellow pine sticks, including longleaf, shortleaf, and loblolly. These were measured in the form of logs, piling, stringers, caps and sills, ties, etc.

As a result of these measurements, the Committee recommends, for a preliminary consideration, that any timber which has 15 or

more annual growth rings per inch, as measured in an average of at least 5 inches across the face of the stick, shall be considered longleaf pine; any timber having an average of 8 to 15 growth rings per inch shall be considered shortleaf pine, and any timber having less than an average of 8 rings per inch shall be considered so porous that it is unfit for structural purposes.

In making these measurements, it will be noted that the average number of rings per inch should be determined by the measurement of at least 5 inches. As the central part of the stick always shows a greater rate of growth than the outside, some of the yellow pine manufacturers have suggested that the first inch, as measured from the heart outward, be not included in the measurement to determine the average number of rings per inch. Until more definite information is at hand, the Committee feels that it is justified in stating that at least 5 inches be measured. These 5 inches shall be measured in such a way as to fairly represent the cross section of the stick. Further measurements may show that it will be desirable to measure a certain number of inches near the heart and a certain number of inches near the sap. The figures 8 and 15 rings per inch are presented as the result of the evidence so far at hand, and should be considered tentative. Further measurements may show that these figures should be changed.

It must be remembered that the specification limiting the amount of sap will also be an additional means of separating desirable and undesirable material in the cases of these three pines.

Mr. Elzner suggested that, should the recommendation to classify pines on the basis of the number of rings per inch be accepted, it might be just as well to drop the terms "longleaf, shortleaf, and loblolly" altogether, and call all Southern pine timbers simply "Southern yellow pine," this to be divided into Grade No. 1 with 15 rings or more per inch, Grade No. 2 with 8 to 15 rings per inch, and Grade No. 3 with less than 8 rings per inch.

Respectfully submitted on behalf of the Committee,

HERMANN VON SCHRENK,

Chairman.

W. K. HATT,
Secretary.

REPORT OF COMMITTEE S ON WATERPROOFING MATERIALS.

Your Committee desires to submit a report of progress. Sub-Committees A and B, the former in charge of waterproofing investigations relative to methods through the treatment of mortars and concretes by the incorporation of foreign substances, non-bituminous in character, the latter relative to methods through the use of bituminous materials applied directly to the surface to be treated, or through cloth or similar mediums, have both pursued the work outlined and reported as under way at the last annual meeting.

Sub-Committee A has been unable to develop any lines of investigation differing materially from those determined upon, but the results of the present year's tests corroborate very generally the conclusion previously noted, with the additional positive information that with even such ungraded materials as crushed quartz or standard Ottawa sand, no difficulty is experienced in a carefully conducted laboratory in obtaining waterproof mortars in such lean proportions as one part of cement to four of sand. There is no excuse for failure when a fairly graded natural sand is used with even leaner mortars, confirming the fact that the necessity of waterproofing treatment with ordinary field concrete mixtures is due either to the use of poor materials, or to poor proportioning or bad handling, or to all of these combined.

We think it has been demonstrated and will be generally admitted, that with proper materials, and proper proportioning and handling of the subsequent mixtures, these need no addition of foreign substances to become initially waterproof; that when such addition is needed for reasons stated above, the desired end can be and is most easily secured mechanically through proper void filling, compensating for the poor proportioning or poor quality of the original constituents. Any chemical action claimed for mixtures operating towards securing waterproof concrete is apparently *nil*. Since void filling is to be sought as the panacea for waterproofing ordinary field concrete, comparative tests through the additions of percentages of colloidal

clay or hydrated lime and the various advertised waterproofing compounds have been carried on continuously, with the conclusion at this date that no general results are obtainable from the use of patented or proprietary compounds which cannot be obtained equally well through the addition of colloidal clay or hydrated lime.

Furthermore, it seems to be very generally proved by corroborative tests, the results of which will be submitted later when including longer time tests, that, as stated in last year's report to be likely, a weakening in tensile strength in time follows the use of many of the patented compounds, which effect is not generally marked when colloidal clay or hydrated lime is used. It has been concluded that the so-called patented compounds fail to remedy defectively proportioned concrete of poor materials as effectively as colloidal clay or hydrated lime, simply because they do not carry sufficient fine material called for by existing conditions. The apparently waterproofing effect of some of these proprietary compounds at early stages, with the very common loss of strength later on, only confirms the opinion as to their temporary effect being entirely mechanical, in aiding through deposits to fill voids to the desired end, which can be permanently better assured by the use of proper percentages of fine material such as colloidal clay or hydrated lime.

It was a more difficult proposition for Sub-Committee B to formulate test methods in the case of bituminous waterproofing materials; for while the manufacturers of these waterproofing materials have been solicited and requested to cooperate with the Committee, since it was considered desirable that where so much depended upon the actual application of the material it was essential that it should be placed by the manufacturers themselves, in accordance with their practical methods, up to the present time only six manufacturers have appeared willing to enter into the program of the Committee. The Committee does not pretend to say why all the manufacturers of such materials should not be willing to join it, but the fact remains that our experiments have been limited, and unless resort is had to the purchase of such materials and the placing of the same under test by members of the Committee apart from any action of the manufacturers themselves, the number of such materials under test must necessarily remain limited.

Our experiments consisted of building concrete tanks, 18 by 12 by 9 ins., in the proportion of 1 part of cement, 3 of sand, and 5 of stone, protected on the inside by each manufacturer with his own material according to his own approved method of application. The methods naturally varied somewhat in individual cases. The bottom and sides of all tanks under treatment were covered with a very lean cement mortar, so as to prevent immediate contact of the waterproofing material with the various liquids with which the tanks were later filled. Holes $\frac{5}{16}$ in. in diameter were previously punched through the 3-in. bottoms of the tanks as originally made and before treatment, so that the effect of the containing liquids, four separate ones being used in every case, might be more rapidly demonstrated by their appearance at the bottom of the tanks. The liquids used were:

1. Astoria gas drip.
2. Seepage water from the sump of the New York Subway at Forty-second Street, which surface water had apparently injuriously affected the bituminous waterproofing material of the original construction.
3. This same seepage water with the addition of 5 per cent. of kerosene by volume.
4. New York city water made alkaline by the addition of about 23 per cent. of potash.

After filling the tanks, they were regularly inspected, but as the results are not complete to date, the attacking effects not being positive in all tanks, it is deemed advisable to withhold any results until complete comparison can be instituted.

Respectfully submitted on behalf of the Committee,

A. W. Dow,
Secretary.

W. A. AIKEN,
Chairman.

REPORT OF COMMITTEE U ON THE CORROSION OF IRON AND STEEL.

An enormous amount of work has been done by your Committee during the past year, partly in cooperation with the American Steel and Wire Company, and the Paint Manufacturers' Association of the United States. The portion of the work which has to do with the investigation of preservative coatings for iron and steel has been carried on under the auspices of a sub-committee selected from the membership of Committees E and U.

The work planned in outline, which was reported to the Society last year and published in the Proceedings, has been carefully carried out. Twelve samples of galvanized steel wire were manufactured by the American Steel and Wire Company, erected in the form of test fences, and exposed to the action of the weather on the grounds of the Carnegie Technical Schools at Pittsburgh, Pa. The twelve samples fell into three groups which will be described in the order in which they were made.

The first sample is a wire of the following composition:

Carbon	0.66	per cent.
Manganese	0.84	" "
Sulphur	0.028	" "
Phosphorus	0.016	" "

This was made at the Newburg Steel Works, Cleveland, Ohio, by the basic open-hearth process. The ingots were cast July 23, 1908, and were reheated and rolled into billets on the same day. On the following day they were again heated to redness and rolled into $\frac{9}{16}$ -in. rods. One billet was taken at random from the lot for the purpose of this test. The rod after cooling was cleaned by immersion in hot dilute sulphuric acid, then rinsed with water and dipped into milk of lime. After drying, the rod was drawn cold into 9-gauge wire. It was then galvanized by passing it through a furnace in which it was heated to dull redness, and then immersing in a bath of hydrochloric acid containing zinc chloride, and lastly in a bath of molten zinc. This wire was not wiped; that is to say, it was allowed to retain as much zinc as

would adhere to it. This sample was designated C-1, and it is purposed to test it against any of the low carbon, low manganese wires to be described later, and which may for this purpose be regarded as C-2.

The second group consists of six samples of "American" style, 8-strand fabricated fencing, 45 ins. high. The object of this group is to determine the effect, if any, of segregation of the impurities in the iron; therefore the six samples were taken from the same heat. The steel was made at the same mill and on the same day as sample C-1, but by the Bessemer process, and was cast in six ingots. As these ingots were rolled, two billets were taken from the top, two from the middle, and two from the bottom, of the first ingot. These three pairs of billets were marked respectively A-1, A-2, and A-3. Similarly, from the last ingot of the heat two billets were taken from the top, two from the middle, and two from the bottom. These three pairs of billets were marked respectively B-1, B-2, and B-3. These were all rolled hot into rods, and after cooling and cleaning in the manner described above, were drawn into wire. The six samples were each divided into three portions. About half of each sample was drawn into 11-gauge wire, a quarter of each sample into 9-gauge wire, and the remaining quarter into 12-gauge wire. This was because these three sizes of wire are all used in making the standard "American" fence, the 9-gauge for the top and bottom horizontal strands, the 11-gauge for the intermediate strands, and the 12-gauge for the vertical connecting wires. Immediately after being drawn the wire was galvanized in the same manner as described for sample C-1, except that on emerging from the molten zinc it was wiped by a mechanical device, which left just a thin, smooth coating of zinc on the steel. A separate piece of fencing about 300 ft. in length was then woven from each of the samples. These six pieces of fencing then represented the top, middle, and bottom of the first and last ingots of the heat respectively. The samples were not analyzed separately, but an analysis of the heat as a whole showed percentages as follows:

Carbon	0.09	per cent.
Manganese	0.55	" "
Sulphur	0.045	" "
Phosphorus	0.092	" "

The third group consists of five samples of basic open-hearth steel showing increasing amounts of manganese from 0.07 to 0.37 per cent. These were all made in one furnace, between August 18-22, 1908. The process of manufacture throughout was identical with that employed on the sample designated C-1, except that the wire was wiped during the process of galvanizing. These five samples were drawn to 11-gauge wire and are designated by their "heat numbers," which are given here together with the analyses.

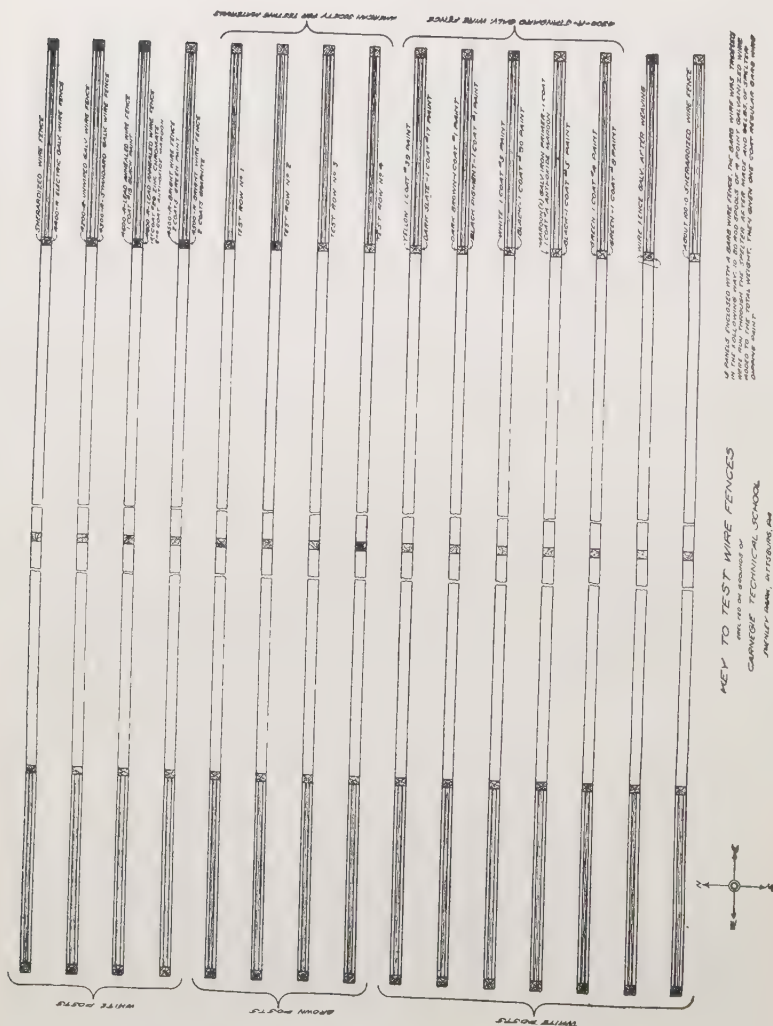
TABLE I.—ANALYSES OF FIVE SAMPLES FORMING THE THIRD GROUP.

Heat Number.	Carbon, per cent.	Manganese, per cent.	Sulphur, per cent.	Phosphorus, per cent.
8118	0.05	0.12	0.014	0.014
8119	0.04	0.07	0.014	0.014
8120	0.05	0.16	0.010	0.010
8121	0.05	0.24	0.018	0.018
8122	0.06	0.37	0.013	0.016

All the wire described above was shipped to Pittsburg, Pa., and was put up in the grounds of the Carnegie Technical Schools between September 23-26, 1908. The site assigned for this purpose is a level strip of ground at the bottom of a deep and narrow natural depression to the north of the quadrangle of school buildings. Because of this location none of the wire will be exposed to the action of wind, but all will show the effects of the fog and dampness which are very prevalent in this hollow.

The fence was constructed in an extremely substantial manner. The posts are 2 x 8-in. dressed oak, the corner posts are 8 x 8 ins., sunk 3 ft. in the ground. The lower ends are painted with a mixture of benzine and asphalt, and the portion above ground with ordinary lead paint. The post holes were filled in with concrete.

There are four parallel lines of posts, 3 ft. apart and 275 ft. long, as shown in Fig. 1. These lines run almost due east and west. The one farthest north is called row No. 1, the next row No. 2, the next row No. 3, and the line farthest south



row No. 4. The arrangement of the wire on these posts is as follows:

On the north side of row No. 1 is placed sample A-1.
“ “ south “ “ “ “ “ 1 “ “ “ “ A-2.
“ “ north “ “ “ “ “ 2 “ “ “ “ A-3.
“ “ south “ “ “ “ “ 2 “ “ “ “ B-1.
“ “ north “ “ “ “ “ 3 “ “ “ “ B-2.
“ “ south “ “ “ “ “ 3 “ “ “ “ B-3.

On the north side of row No. 4 at the top are 8 strands of 8119.
“ “ “ “ “ “ “ “ “ “ middle “ “ “ “ C-1.
“ “ “ “ “ “ “ “ “ “ bottom “ “ “ “ 8118.
“ “ south “ “ “ “ “ “ “ “ top “ “ “ “ 8122.
“ “ “ “ “ “ “ “ “ “ middle “ “ “ “ 8121.
“ “ “ “ “ “ “ “ “ “ bottom “ “ “ “ 8120.

In the first three rows the posts are 15 ft. apart and in the fourth row 30 ft. apart. The wire was all stretched as tightly as possible to prevent sagging, and none of it is less than 1 ft. above the ground.

In addition to the test fences described above, a number of panels have been mounted in order to test different methods of providing protective coatings for ordinary steel wire fences. One panel of American style, woven wire fence is galvanized by the cold or electroplating process; another panel is made of double galvanized wire carrying about the same weight of zinc as is usually specified for telegraph wire. This wire was galvanized by a special adaptation and variation of the ordinary hot-dip process, and was not previously subjected to the acid bath. A third panel is coated with zinc by the Sherardizing process. Ten panels, in part galvanized by the ordinary hot-dip process and in part ungalvanized, have been protected by painting with various protective paint coatings. All of these extra panels have been mounted in exactly the same manner and side by side with the samples already described in the foregoing, and the tests should in the course of time yield results of great value.

It has come to the attention of the Committee that the conditions for uniformity in carrying out an accelerated acid test to determine the rate of solution as a possible measure of tendency to corrosion, which was contained in this Committee's report

of 1907, has been misinterpreted by some as a standard method proposed by the Committee. This is not the case. It was merely the intention of the Committee, that those who cared to make such an acid test should use certain uniform conditions as to concentration of acid, size of specimen, time of immersion, etc., in order that the results thus obtained should be comparable, with a view of determining whether the results of such a test bore any relation whatever to corrosion as observed in service. The results so far obtained show that the test is not generally applicable, and in some cases may be very misleading.

Respectfully submitted on behalf of the Committee,

W. H. WALKER,
Secretary.

ALLERTON S. CUSHMAN,
Chairman.

DISCUSSION.

MR. J. P. SNOW.—Two years ago, when this Committee Mr. Snow. made its first report, there was quite a little discussion as to the relative rate of corrosion of ordinary steel and puddled iron. Since then the discussion has been continued with more or less vigor. At the meeting two years ago, after contending that steel rusted much more rapidly than puddled iron, I had a conversation with Mr. Cushman, Chairman of the Committee, and I told him that I could send him some samples which would illustrate the point pretty fully. I stated that the specimens referred to were taken from a signal bridge which was built about 1893 and stood in place over the tracks a matter of ten years, with very little attention; and then for operating reasons the structure was removed and thrown into the scrap heap. I noticed that there was a great difference in the amount of corrosion in different portions of that bridge. Pieces that were riveted together where two angles crossed with a union plate between them, showed very unequal effect from the action of the gases. In some instances one of these parts was entirely gone, and the other part not very much corroded. Mr. Cushman said he would be very much interested to get such samples, and I sent him in the course of a couple of months or so quite a box-full. The collection contained, besides various pieces from the bridge above described, a number of samples of pipe which had been used for line pipe in signal plants, in which the pipe was rusted to lace work, while the couplings were intact.

At the time of sending these samples, I did not make any tests to distinguish iron from steel, thinking the Chairman would do that, but the only report that I have been able to get was that there was no real difference between the part which rusted and that which did not rust, except that one was a little more inhibitive to corrosion than the other. The tests which Mr. Cushman made to distinguish puddled iron from steel, I infer were made chemically. I was not satisfied with that sort of treatment, and this summer I visited the scrap heap and found several samples

Mr. Snow. of the same signal bridge left that showed this difference of action pretty plainly. I cut out quite a lot of them and tested them in my way of distinguishing iron from steel, that is by nicking across and bending over to develop the internal structure. In every single case I found that the part which did not corrode seriously was puddled iron, and that the part which did corrode was steel.

I have a sample with me which shows the difference distinctly. This part of the iron is one leg of an angle; the other part is a piece of the gusset plate to which the angle was riveted, both parts being originally $\frac{1}{4}$ in. thick. The angle is pretty nearly of its original thickness. What is left of the steel plate was nicked and fractured through the portion where the rivet was driven and the steel showed characteristic homogeneity. This bridge was built about 1893. That was about the transition period between puddled iron and steel for bridge material. This bridge was one of a large number that were purchased, which we wanted quickly, and we expected that the builders would make them out of whatever stock they had on hand. As these signal bridges are subjected to scarcely any load, no specifications for material were required, and as a result almost anything that they had on hand was picked up and put into the structure; some of it steel, and some of it wrought iron.

I have another little sample which was cut from a water tank hoop which, when removed, had been in service three years. It had rusted through during those three years. We have in many instances water tank hoops which have been in service thirty years, subjected to exactly the same conditions that this was, they of course being wrought iron. This by its fracture is shown to be steel.

I do not know that these facts prove anything, but they do make the report complete on the samples that I sent to this Committee. I do not think much of a chemical test to distinguish wrought iron from steel. Take the case of "ingot iron," so called. We are told it is 99.9 per cent. iron. How is a chemist to tell whether it was made on a puddling hearth or cast in an ingot mold? The method of manufacture, it seems to me, marks the difference between the two metals as regards rapidity of corrosion.

There are three kinds of metal that should be distinguished Mr. Snow.
in this discussion. Ingot metal, called steel in this country, puddled iron, made in a puddling furnace from pig iron and ore, and fagot iron, of which large amounts are now on the market made from scrap, cut, piled and re-rolled. As much of the scrap entering into its make-up is steel, its resistance to corrosion is quite likely not so marked as that of puddled iron.

This fagot iron shows a characteristic fracture when nicked or broken, similar to that of puddled iron; but it generally breaks with more crystals in the fracture than puddled iron proper; so that it can be distinguished in that way. It corrodes very nearly as freely as steel. In practical service, real puddled iron made from proper material, so far as I have been able to observe, resists corrosion by engine gases much better than steel. I know that scientists are loath to admit this, but I simply state what I have observed as facts.

MR. W. H. WALKER.—May I say a word in reply to Mr. Mr. Walker.
Snow? The samples which he mentions were never submitted to Committee U, and it is therefore impossible for the Committee to report thereon.

Further, I would like to point out that it lays one open to a charge of "unfair treatment" to judge one kind of iron in a structure where it is electrically connected to another kind of iron. When thus connected one kind will very probably show a higher potential than the other and thus corrode more rapidly than if the structure were composed of this one kind of iron alone. A sweeping statement that steel is better than wrought iron or vice versa, is without value. I have data upon which I could write a brief which would convincingly prove that wrought iron is better than steel. I have other data from which it could be argued with equal conviction that steel is better than wrought iron. It all depends as to whether one is considering good wrought iron and bad steel, or good steel and bad wrought iron. Generalizations should always be made with the greatest care.

MR. H. M. HOWE.—I think that it is an important truth, Mr. Howe.
that some steel is not fit to be used under conditions where it will be exposed to corrosion; whereas there is other steel that is fit. There is no doubt that some steel rusts very badly, but there is the very important question as to whether the conditions of manu-

Mr. Howe. fracture which yielded readily corroding steel have or have not been overcome. Considerable evidence was presented last year to show that these conditions had been overcome at least to a very great degree, and that there was not in the particular specimens shown a marked difference in corrodibility between that steel and the wrought iron tested in competition with it.

Mr. Speller. **MR. F. N. SPELLER.**—It is not clear as to whether the sample brought to our attention is steel or iron, but the method of making the observations is interesting and one that everybody can apply if he will take the trouble to examine old material. We have made use of this method of testing old material in service with considerable benefit. The criticism has been offered that short time tests do not teach anything. I am not prepared to agree with that; in fact, the evidence we have shows that tests can be made under certain conditions, which in one or two years will give results comparative with ordinary service covering fifteen or twenty years. In the world to-day, however, we have plenty of opportunities of comparing iron and steel and other classes of material that have been mixed up in service.

Mr. Snow's remarks suggested some experience that we have had personally on that line, in connection with investigations which we had the opportunity of making on pipe material at the Panama Canal. The question came up as to whether wrought iron or steel was best adapted to withstand the severe conditions of tropical climate. A good many were of the opinion that wrought iron should be used, contending that the old French material was all wrought iron, and that some of it had stood up so well that its use should be continued at the present time. In cooperation with the division engineers all along the route, we investigated every case that could be found of old piping where there was any considerable amount left. We took samples from various lengths of pipe, and without knowing the character of the material, made notes as to the condition it was in. We investigated in all about 150 cases, out of which number we found somewhere between 20 and 30 iron and steel pipes which had been in service together under the same conditions at various places on the Isthmus. The larger portion of the material, three-fourths of it at least, was wrought iron; but there was enough steel for comparison, and it was steel made at least twenty years ago when the

methods of manufacture were not so refined as they are now. **Mr. Speller.** In not one of these cases was there anything in the comparison that would reflect at all on the steel.

If a pipe line fails, whether it turns out to be wrought iron or steel, it is interesting to look over the whole system to see if by some chance other material has not been included. The conclusion reached by such observation confirms the result of special tests made by Mr. Howe and others, which go to prove that the difference between iron and steel has been greatly exaggerated.

The samples which Mr. Snow has produced should be analyzed, as it is not always possible to tell by a fracture test whether the material is wrought iron or steel. This reminds me of a case that came up at a meeting of the Society of Heating and Ventilating Engineers, when this subject was being discussed. An engineer brought forward a sample of a nipple that had failed after less than a year's service connected with a steam radiator. He had examined the nature of the pitting and pronounced it to be steel. Somebody advised that the material be etched and analyzed before the matter went on record, which was done, and the piece proved to be wrought iron. That does not prove anything against wrought iron in favor of steel; but it is a caution to those who would jump at conclusions. There are plenty of opportunities for making this comparison. So far as pipe material is concerned, after many such experiences I have yet to find a case where there is any great difference. Sometimes steel will show a little worse than iron and at other times the iron pits deeper than the steel, depending upon whether it be good iron or good steel. I have gone on record as to the necessity for good material in pipe, or anything else that is exposed to corrosion, and believe that by making a good, uniform quality of steel and working it well, we have a material which is better than the average grade of wrought iron that has been used in the past, or is being made to-day for this purpose.

MR. J. O. HANDY (by letter).—I would like to call attention **Mr. Handy.** to the misinterpretation by the sheet metal trade of the results of the "sulphuric acid corrosion test" proposed by Committee U in 1907, alluded to in 1908, and again in the report just submitted.

In the 1908 report (see Vol. VIII, p. 233) it is stated that: "It is not yet possible to state definitely whether the results of the

Mr. Handy. acid test are an indication of the rust-resisting power of the metal;" and in the same paragraph: "So far no better test has been proposed." Tables are shown giving results of both acid corrosion and corrosion under water. These prove conclusively the utter failure of the acid test to give results which are comparable with those obtained under service conditions. Although Bessemer steel and wrought iron are about equally corroded during long exposure under fresh or salt water, they show great differences by the acid test; while other discrepancies are also evident upon further examination.

Why should there be any further question as to the value of the acid test as an index to the resistance of steel and iron to corrosion? It seems to me that the Committee should go further than to say that it is not a standard test and that they do not recommend it; they should frankly condemn it. It has already been given undue standing by the prominence which they have given it in their reports.

Mr. Cushman. MR. A. S. CUSHMAN (by letter).—I received the samples which Mr. Snow sent me two years ago and was much interested in examining them at that time. I did as much work on them as the pressure of official duties and other investigations permitted. I succeeded in convincing myself at that time that the badly rusted samples were steel, while those which were in a better state of preservation were iron. I believe this conclusion has been substantiated by Mr. Snow's tests. It happened that about the same time another interesting case of corrosion of an assembled structure had been brought to my notice, in which the iron members had completely failed and the steel had not suffered damage. At the time I was at a loss to find an explanation for these apparently contradictory results, except by the well-known fact that there are good steels and bad steels, just as there are good irons and bad irons. Recent investigation and observation have convinced me, however, that when two different kinds of metal are assembled and connected in the same structure one will invariably assume the rôle of electro-positiveness to the other. The electro-positive metal will, therefore, be destroyed by corrosion very much more rapidly than if it were built into a structure by itself. In the light of this knowledge, it would be impossible to say that an all-iron structure would outlast an all-steel structure, for as a matter of

fact in cases of this kind one type of metal is accelerating the corrosion of the other. Mr. Cushman.

In regard to the acid test referred to by Mr. Handy, I can only say that I have frequently expressed strong doubts as to whether it had any direct bearing on the resistance to corrosion under service conditions. I am now willing to say that I do not think it can be taken under any circumstances as a measure relative of rust resistance. I do not, however, agree with Mr. Handy that the test should be condemned, as it is extremely valuable in many ways in studying the heat treatments of steel. One of the strongest and most instructive papers that has recently come to my attention is that of Heyn and Bauer, published in the *Journal of the Iron and Steel Institute*, 1909, on the solubility of steel in sulphuric acid. These authors, after the most comprehensive and careful research, have shown that not only can much be learned by the acid test, but that indirectly it furnishes information in regard to the rust-resistant qualities of various types of metal in different physical conditions. This is, of course, not the same as saying that the acid test can be used as a measure of the relative rust-resisting qualities of different samples of iron and steel. I consider the test a valuable one when carried on for the purpose of investigation, and the fact that it has been misused to a considerable extent in a commercial way is not sufficient reason in my judgment for condemning it.

Committee U has always endeavored to be extremely conservative in regard to the acid test and has pointed out in specific language that it should not be used as the basis of any claims whatsoever in regard to the relative rust resistance of metals.

REPORT OF COMMITTEE V ON
STANDARD SPECIFICATIONS FOR COLD-DRAWN
STEEL.

Your Committee has held two meetings, one in Pittsburg and one in New York. At the first meeting the Committee formed a permanent organization, and outlined a general plan of work. At this meeting the Committee also decided tentatively certain general questions, as follows:

Definition of Cold-drawn Steel.—The Committee decided to restrict its work, at least for the present, to material which would come under the following definition: "Bars, either cold-drawn or cold-rolled to finished size from hot-rolled steel."

Classification or Grading of Material.—The Committee decided to consider material covered by the above definition, under the following classifications: (a) standard axle stock, (b) standard shafting stock, (c) standard machining stock, (d) standard automatic screw stock.

Tests.—At the second meeting of the Committee, in the discussion of tentative specifications covering the items of dimensional limits, physical tests, chemical analyses, etc., it became evident that additional data in regard to a number of points, particularly with reference to material used for machining at very high speed, were necessary before definite specifications could be agreed upon. In view of this fact, it was decided to carry out a series of tests to determine some of the features which would affect the working qualities and physical characteristics of standard automatic screw stock. These tests will necessarily take considerable time, and it was not considered advisable to attempt specifications covering the other grades of material until the characteristics of the automatic screw stock have been determined, as there are many points in common between it and the other stocks.

The work of the Committee to date can therefore be summarized in the one word "progress."

C. E. SKINNER,
Chairman.

REPORT OF COMMITTEE W ON STANDARD SPECIFICATIONS FOR HARD-DRAWN COPPER WIRE.

Committee W was appointed in pursuance of a resolution adopted at the annual meeting in 1908, that the Executive Committee be requested to consider the desirability of creating a committee having for its object the preparation of specifications covering hard-drawn copper wire. The subject first authorized by the Executive Committee was "Hard-Drawn Copper and Copper-Alloy Wire"; this was afterwards changed to "Hard-Drawn Copper Wire."

Committee W held its first meeting in New York City, April 2, 1909, nine of the ten members being present. After organization, it was decided that the work for this year be confined to the preparation of such specifications for hard-drawn copper wire as could confidently be offered for adoption by the Society as standard specifications.

The rough outlines of the proposed specifications were discussed, and the points that should necessarily be covered by the specifications were agreed upon. The representatives of the manufacturers on the Committee were then constituted a subcommittee to consider and submit values and limits for the various points decided upon. In discussing the points to be covered, all of the tests and requirements included in the specifications already more or less common were taken up in detail, and many of the tests were discarded because of the difficulty of making them or of the uncertainty of the results obtained. It was the unanimous decision of the Committee that they would recommend only such tests and requirements as are definite, and can be made and repeated with reasonable assurance of the substantial duplication of results; but that in the report accompanying the proposed specifications, adequate explanation would be given of the reasons for the omission of certain requirements that have been commonly included in specifications for copper wire, and for the rather different method of stating some of the requirements retained.

A second meeting of the Committee, with full membership in attendance, was held in New York City, May 8, 1909, at which time the Sub-Committee of the manufacturers' representatives reported the proposed values and limits; and after a six-hour session the specifications with the accompanying explanations, appended to this report, were agreed upon. Your Committee feels that these specifications may safely be adopted for the next year, at least. There are a few points which may need slight revision as the result of experience gained while working under them, but we feel that such changes will not be numerous or material.

Respectfully submitted on behalf of the Committee,

J. A. CAPP,
Chairman.

NOTE.—The Specifications for Hard-Drawn Copper Wire were adopted by letter ballot of the Society on August 16, 1909, and follow this report.—ED.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR HARD-DRAWN COPPER WIRE.

ADOPTED AUGUST 16, 1909.

1. The material shall be copper of such quality and purity **Material.** that, when drawn hard, it shall have the properties and characteristics herein required.

2. These specifications cover hard-drawn round wire, **Shapes.** grooved trolley wire and hard-drawn cable or strand, as herein-after described.

3. The wire, in all shapes, must be free from all surface **Finish.** imperfections not consistent with the best commercial practice.

4. (a) Package sizes for round wire and for cable shall be **Packages.** agreed upon in the placing of individual orders; standard packages of grooved trolley wire shall be shipments upon reels holding about 2,500 lbs. each.

(b) The wire shall be protected against damage in ordinary handling and shipping.

5. For the purpose of calculating weights, cross sections, etc., **Specific Gravity.** the specific gravity of copper shall be taken as 8.90.

6. All testing and inspection shall be made at the place of **Inspection.** manufacture. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to enable him to satisfy himself that the material conforms to the requirements of these specifications.

HARD-DRAWN ROUND WIRE.

Dimensions and
Permissible
Variations.

7. (a) Size shall be expressed as the diameter of the wire in decimal fractions of an inch, using not more than three places of decimals; i. e., in mills.

(b) Wire is expected to be accurate in diameter; permissible variations from nominal diameter shall be:

For wire 0.100 in. in diameter and larger, one per cent. over or under.

For wire less than 0.100 in. in diameter, one mill over or under.

(c) Each coil is to be gauged at three places, one near each end, and one approximately at the middle; the coil may be rejected if, two points being within the accepted limits, the third point is off gauge more than 2 per cent. in the case of wire 0.064 in. in diameter and larger, or more than 3 per cent. in the case of wire less than 0.064 in. in diameter.

Physical Tests

8. The wire shall be so drawn that its tensile strength and elongation shall be at least equal to the values stated in the following table. Tensile tests shall be made upon fair samples, and the

Diameter, inches.	Area, circular mills.	Tensile Strength, lbs. per sq. in.	Elongation in 10 ins., per cent.
0.460	211,600	49,000	2.7
0.410	168,100	51,000	2.6
0.365	133,200	53,000	2.4
0.325	105,600	54,500	2.3
0.289	83,520	56,000	2.1
0.258	66,560	57,500	2.0
0.229	52,440	58,500	1.9
0.204	41,620	59,500	1.8
0.182	33,120	60,500	1.7
0.162	26,240	61,500	1.6
0.144	20,740	62,500	1.5
0.128	16,380	63,400	1.4
0.114	12,996	64,200	1.3
0.102	10,404	64,800	1.2
0.091	8,281	65,400	1.1
0.081	6,561	65,700	1.0
0.072	5,184	66,000	0.9
0.064	4,096	66,200	0.9
0.057	3,249	66,400	0.8
0.051	2,601	66,600	0.8
0.045	2,025	66,800	0.7
0.040	1,600	67,000	0.7

elongation shall be determined as the permanent increase in length, due to the breaking of the wire in tension, measured between bench marks placed upon the wire originally 10 ins. apart. The fracture shall be between the bench marks, and not closer than 1 in. to either mark. If, upon testing a sample from any coil of wire, the results are found to be below the values stated in the table, tests upon two additional samples shall be made, and the average of the three tests shall determine acceptance or rejection of the coil. For wire whose nominal diameter is between listed sizes, the requirements shall be those of the next larger size included in the table.

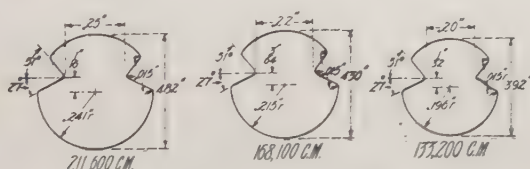
9. Electric conductivity shall be determined upon fair samples by resistance measurements at a temperature of 20° C. (68° F.). The wire shall not exceed the following limits: Electric Conductivity.

For diameters 0.460 in. to 0.325 in., 900.77 lbs. per mile-ohm at 20° C.

For diameters 0.324 in. to 0.040 in., 910.15 lbs. per mile-ohm at 20° C.

GROOVED TROLLEY WIRE.

10. Standard sections shall be those known as the "American Standard" grooved trolley wire sections, the shape and dimensions of which are as follows: Sections.



11. (a) Size shall be expressed as the area of cross section in circular mills, the standard sizes being as follows: Dimensions and Permissible Variations.

211,600	circular mills,	weighing	3,386	lbs. per mile.
168,100	"	"	2,690	" " "
133,200	"	"	2,132	" " "

(b) Grooved trolley wire may vary 4 per cent. over or under in weight per unit length from standard, as determined from the nominal cross section.

- Physical Tests.** 12. The physical tests shall be made in the same manner as those upon round wire. The tensile strength of grooved wire shall be at least 95 per cent. of that required for round wire of the same sectional area; the elongation shall be the same as that required for round wire of the same sectional area.
- Electric Conductivity.** 13. The requirements for electric conductivity shall be the same as those for round wire of the same sectional area.

HARD-DRAWN COPPER WIRE CABLE OR STRAND.

- Construction.** 14. For the purposes of these specifications, standard cable shall be that made up of hard-drawn wire laid concentrically about a hard-drawn wire center. Cable laid up about a hemp center or about a soft wire core is to be subject to special specifications to be agreed upon in individual cases.
- Wire.** 15. The wire entering into the construction of stranded cable shall, before stranding, meet all the requirements of round wire, hereinbefore stated.
- Physical Tests.** 16. The tensile strength of standard cable shall be at least 90 per cent. of the total strength required of the wires forming the cable.
- Brazes.** 17. Brazes, made in accordance with the best commercial practice, will be permitted in wire entering into cable; but no two brazes in wire in the cable may be closer together than 50 ft.
- Lay.** 18. The pitch of standard cable shall be not less than 12, nor more than 16, diameters of the cable. The cable shall be laid left-handed or right-handed, as shall be agreed upon in the placing of individual orders.

EXPLANATORY NOTES ON STANDARD SPECIFICATIONS FOR HARD-DRAWN COPPER WIRE.

5. The specific gravity of copper has been commonly accepted as 8.9, and this value is retained in these specifications. The maximum variation from this figure in a large number of samples of wire has not been sufficient to lead one to anticipate any serious error from its use as a flat value in calculations.

7. (a) The use of arbitrary gauge numbers to express dimensions cannot be too strongly condemned. There are many such gauges in existence, and confusion is to be expected unless the

particular gauge to be used is specified. Many of the gauges have their dimensions stated in absurd figures, such as 0.090742 in., when it is not especially easy to measure dimensions in the fourth decimal place by workshop tools. Definite diameters in measurable units are evidently preferable.

8. Many other physical tests than those provided in these specifications are included in existing specifications. The reasons for the omission of some of the more common are given as follows:

Twist Tests.—The wire is sometimes required to permit twisting through a stated number of revolutions before breaking. The results are so easily influenced by temperature, speed of rotation, method of gripping, and other variables not easily defined or controlled, that the test is at least of doubtful value. It is the opinion of the Committee that it is impractical to so define the conditions of the test that a twist test can be made definite and reliable; hence there is no warrant for its inclusion in specifications.

Wrap Tests.—Wire is sometimes required to permit tight wrapping about a wire of its own diameter, unwrapping and again re-wrapping. It is obvious that the making of a test of this kind with wire that is already hard-drawn is exceedingly difficult. Every one who has tried to break off a piece of tough wire by bending it back and forth between the fingers knows how hard it is to confine the bend to one place, because of the hardening action of the previous bends. Hard wire which has been wrapped around a wire of small diameter is hardened still more and it is almost impossible to straighten the wire, let alone re-coil it in the opposite direction. In the opinion of the Committee, it is inadvisable to include a test which at best is so indefinite as a wrap test. Furthermore, it is the opinion of the Committee that wire which will meet the physical tests included in these specifications will meet any properly made twist or wrap test that would reasonably be required.

Elastic Limit.—During the tension test on wire, there is seldom to be observed any definite drop of the beam or increase in the rate of elongation, corresponding to the yield point commonly observed in testing steel. The only way in which the elastic limit of hard wire may be determined is by the actual plotting of the elastic curve from extensometer readings. Even such tests are difficult of interpretation, because the wire when available for tests

is usually curved, due to its having been put up in a coil. There are little sets observable before the true elastic limit has been reached, owing to the fact that one side of the wire, having been stretched in coiling, is really a little harder than the other side, and the pull is, therefore, not even. Considering the difficulty of making the test and the uncertainty of the results obtained, it is the opinion of the Committee that it would be inadvisable to include an elastic limit test in these specifications. It is evident that if the designing engineer requires a knowledge of the location of the elastic limit for purposes of calculation in designing, such data can be obtained by special tests on representative sizes of wire, which will fix the relation of the elastic limit to the ultimate strength for all wire which is properly made.

Elongation.—Elongation tests on wire are required in different specifications to be measured in lengths varying from 8 to 60 ins. The elongation has variously been measured as the permanent increase in the length of the wire, measured between bench marks placed on the wire before fracture; as the elongation measured between the jaws of the testing machine, which are adjusted to grip the wire with a certain definite free length; and in various other ways. Perhaps the most commonly used length is 10 ins., and it is a good length, because measurements may be immediately transposed into percentages without laborious calculation. Measurement of elongation in any other way than as the permanent increase in length between bench marks, in the manner customary in the measurement of elongation of steel specimens, is open to criticism. If measurements are made between the jaws of the testing machine, there is included a certain amount of elongation which has taken place within the jaws, because the wire in stretching will have been reduced in diameter and, therefore, have stretched to a greater or less extent within the jaws themselves. If the measurement is made between bench marks on the wire just prior to breakage, there is included in the elongation a certain amount of elastic deformation.

9. Electric conductivity is usually expressed as a percentage on the Matthiesen basis, reference being made to determinations of the electrical resistivity of supposedly pure copper by Matthiesen, about 1865. Since that time, the methods of refining copper have greatly improved, so that to-day it is not uncommon to find copper

of over 100 per cent. conductivity on the Matthiesen basis. Furthermore, what the electrical engineer requires is that the wire shall not exceed a certain maximum electrical resistance. It seems obvious that it is less laborious to express quantities in direct definite terms, rather than by reference to something else which requires interpretation before the results are ready for use in calculation. Resistivity is commonly expressed in a number of different ways, all being equivalent to the resistance of some unit of cross section, this unit being expressed either in linear dimensions or as a combination of weight and dimensions. For convenience, we give a table of equivalents of the values for electrical resistance included in these specifications. The values are equivalent respectively to 97 per cent. and 96 per cent. conductivity on the Matthiesen basis.

900.77 lbs. per mile-ohm is equal to:

0.15776 ohms per meter-gram,
1.7726 microhms per centimeter-cube,
0.69789 microhms per inch-cube,
10.663 ohms per mill-foot.

910.15 lbs. per mile-ohm is equal to:

0.15941 ohms per meter-gram,
1.7911 microhms per centimeter-cube,
0.70517 microhms per inch-cube,
10.774 ohms per mill-foot.

10. It is obvious that the simplest designation of irregular shapes of similar outline is by sectional area, and the most commonly used unit among electrical engineers is the circular mill. Therefore, while the sizes of grooved trolley wire regularly used are generally known by B & S gauge number, corresponding to their sectional area, it has been deemed advisable by the Committee to list these sizes, in specifications, by their sectional area expressed in circular mills. The three sizes which are most extensively used commercially are the only ones listed; a fourth size is but little used, and the use is growing less.

11. The only way in which gauge variations are easily determinable in irregular shapes is by recourse to weights of standard lengths, and this has been the method adopted in the specifications.

14. So many variations in the construction of cable are possible that it has been deemed inadvisable to complicate the specifications by including requirements for any other than the one type most commonly used.

16. Physical testing of cable is at best a difficult matter, and the measurement of elongation in cable which has been subjected to a tensile test is uncertain, since it includes the elastic deformation of the cable as a spring, the actual elongation of the wires, and perhaps even some elastic deformation of the wires as such. It is, therefore, thought inadvisable to include a requirement covering an elongation test.

17. The permitting of brazes in wire entering into the construction of copper cable was discussed at considerable length, and it is finally the opinion of the Committee that, provided no two brazes are closer together than 50 ft., the cable has fully 90 per cent. of the theoretical strength obtained by adding together the required strengths of the constituent wires. This is due, in such long lengths, to the frictional gripping of the wires in the cable. The construction of long lengths of cable without brazes is costly, and it has been thought best, therefore, to permit their use, provided they are sufficiently widely spaced as not to be detrimental to the strength of the cable.

NOTES ON TESTS OF INGOTS AND DERIVATIVE SHAPES IN PROGRESS AT WATERTOWN ARSENAL.

BY JAMES E. HOWARD.

The question which claims early attention in the examination of ingots and derivative shapes, is that of structural soundness and uniformity, the lack of which may result from the partial welding of interior cavities or from the presence of foreign material, slag of whatever chemical composition it may be. The present tests have been arranged in a manner intended to develop information on the causes which detract from soundness of structure, and to aid in attaining this end the material from the ingot, through the several reductions to the finished rails, is being examined as it is revealed on both longitudinal and transverse sections of the different shapes. This part of the inquiry has required a considerable amount of machine work in cutting up the material, and in polishing and etching the sections, so that photographic records could be obtained.

This preliminary work is largely of an illustrative nature, in which the successive changes in appearance of the steel are followed from pass to pass. In this manner it is believed that explanatory data will be acquired, and the significance of those markings which characterize etched steel surfaces in general be made known. A large number of photographic negatives represent the status of the work at the present time.

Beginning with the ingot, the longitudinal and cross sectional slices showed to the unaided eye those cavities due to gases or shrinkage which are commonly found in the ingot. Upon smooth polishing it was found convenient to acquire information upon entrained slag, locating the zones in which slag in globular form was present, counting the number of such globules, and measuring their diameters. The positions of the slag zones changed in going from the bottom toward the top of the ingot. When the upper portions were reached, where blowholes were encountered, the slag was found to have gathered in larger beads and rested



FIG. 1.—Photomicrograph, showing slag globule as found in steel ingot. Globule surrounded by ferrite. Magnification, 57 diameters.



FIG. 2.—Photomicrograph, showing slag globule as found in steel ingot. Globule not surrounded by ferrite. Magnification, 62.5 diameters.

on the lower walls of the cavities. The appearance of these slag globules is shown in Figs. 1 and 2. In one photograph the globule is surrounded by ferrite; in the other it is not.

Upon etching these slices with tincture of iodine, a fern-like interlacing structure was shown in the metal adjacent to the sides of the ingot, within which a mottled surface was located. The appearance of the surface developed by the iodine was



FIG. 3.—Cross section of steel ingot near bottom end. Structure developed by picric acid. Natural size.

dissimilar to that brought out by etching with picric acid. It was found that both structures, that developed by iodine and that by picric acid, could be shown simultaneously on the same specimen.

Fig. 3 shows the structure of a section taken near the bottom of an ingot developed by picric acid. The elongated grains next the sides of the ingot are shown oriented with their longer axes normal to the cooling surface of the ingot, while within are found grains differing in size but undistorted in their shapes.

Fig. 4 shows both structures, the iodine having been employed on the sample after it had been etched with picric acid. The fern-like structure is present in a number of the subsequent passes, but is lost before the final passes of the rail are reached. In the bloom it is faintly visible. The mottled portions are more or less nebulous and indistinct. As the metal is reduced in the



FIG. 4.—Cross section of steel ingot near bottom end. Structure developed by etching sample with tincture of iodine after the same had been etched with picric acid. Natural size.

rolls the markings generally become more sharply defined, but it will be borne in mind that the intensity of these streaks and darkened places will appear very differently according to the conditions of etching.

Slag inclusions which are globular in the ingot are gradually extended as the metal is rolled down. Fig. 5 shows the appearance of a streak, viewed longitudinally, in metal after the ninth pass from the ingot. When viewed in cross section, this and

similar places in the steel showed rounded or approximately circular boundaries.

It seems reasonable to suppose that the starting places of streaks or hair-line cracks are at the ingot where slag inclusions are initially found. The query suggests itself, whether a hair-line crack may not extend during the rolling of the metal for a greater distance than the slag itself is drawn out. Such seemed to be the case in the specimen represented in Fig. 5. The large number of slag globules which may be present in parts of the ingot are sufficient to account for the short, fine lines or cracks numerous in certain rails which have been examined.

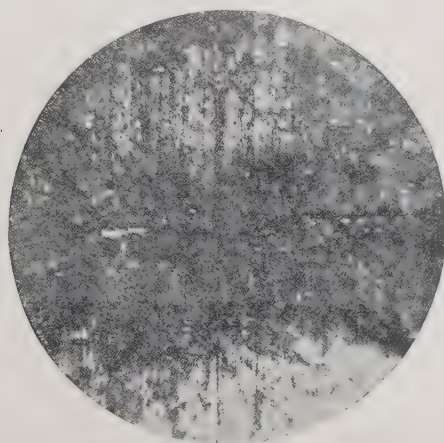


FIG. 5.—Streak in metal after ninth pass from ingot. Magnification, 40 diameters.

In regard to gas cavities, blowholes, or shrinkage cracks in the ingot, they disappear from ordinary view quite promptly as the metal is reduced in the rolls. In the final examination of the steel in the finished rail, however, those parts of the ingot which contained most of the blowholes furnish rail sections containing the largest number of streaked lines.

It is further significant that an ingot laid on its side to cool, immediately after stripping, web side up with reference to the rails subsequently rolled therefrom, furnishes rails in which evidence of this treatment is present in nearly all of the rails

from whatever part of the ingot they came. Fig. 6 shows the characteristic markings on the cross section of a rail from such an ingot, and the location of the streaks on that side which was uppermost when the ingot cooled.

Some special tests were made on the welding of rail steel, using the stems of tensile specimens for the purpose. Polishing and etching the best parts of the welds made on these specimens, the welding having been done in the open air, gave the results



FIG. 6.—Photograph of cross section of rail from ingot laid on side to cool immediately after stripping, showing streaks located on side uppermost in ingot.

shown in Figs. 7 and 8. While the junction of the two parts may be easily seen, still there are crystals which extend over this line.

In the case of the granular structure of the ingot, as developed by etching with picric acid, and illustrated in Fig. 3, lines of rupture followed the boundaries of the elongated grains when the metal was fractured by a transverse load. Tests of a similar kind were made on steel from one of the intermediate passes in

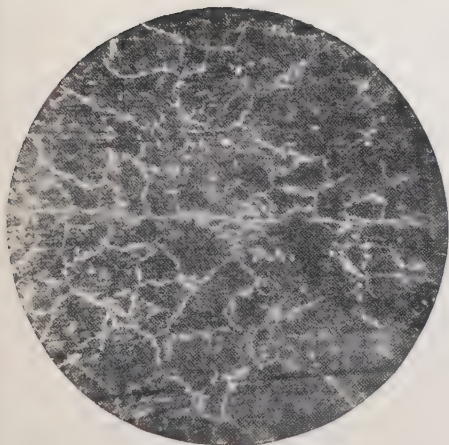


FIG. 7.—Photomicrograph of weld in rail steel. Magnification, 50 diameters.

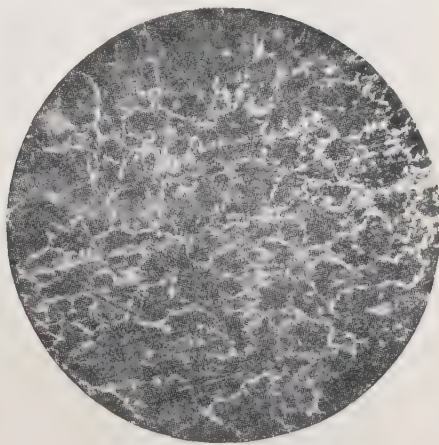


FIG. 8.—Photomicrograph of weld in rail steel. Magnification, 50 diameters.

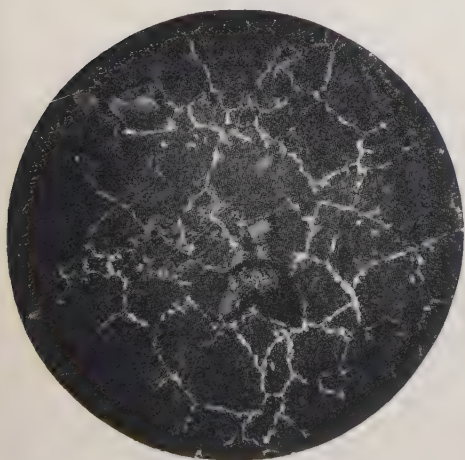


FIG. 9.—Photomicrograph of section of rail steel from an early pass, showing appearance before compression loads were applied. Magnification, 50 diameters.

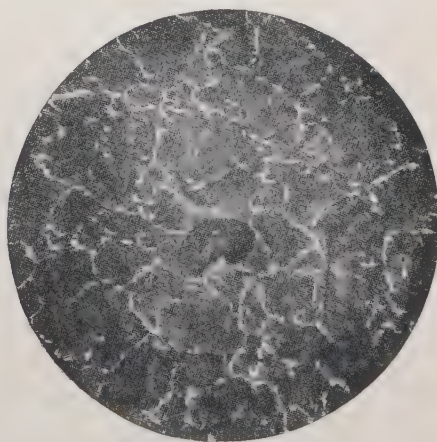


FIG. 10.—Photomicrograph of section of rail steel from an early pass, showing appearance after compression loads were applied. Fractures developed along ferrite line. Magnification, 50 diameters.

which metal having a coarse grain was selected. Figs. 9 and 10 show the appearance of the metal before and after loads of compression were applied, the effect of the loads being to cause fractures separating the metal along the ferrite lines. Marks seen near the centers of the photomicrographs were made by a needle point, for the purpose of identification.

In conclusion, it may be said that the markings commonly brought out on the cross sections of steel rails by etching are believed to be those which have their origin in the ingot, modified by subsequent treatment, and that the state of the metal in the ingot, as regards presence of slag and zones differing in structure at this stage, carries through the several passes to the finished rail.

THE CLOSING OF BLOWHOLES IN STEEL INGOTS.

BY HENRY M. HOWE.

Is the sealing of blowholes hermetic, so that the whole of the gas which they initially contain must always remain in them as gas, no matter what the conditions of rolling or forging may be? Or is it un-hermetical, so that there is some way in which the gas may escape? The question seems to me a simple one; either there is or there is not a path of escape. If there is, if the evidence makes it on the whole probable that there is less gas remaining as gas in the relics of the blowholes which persist, for example, in a boiler plate, than there was in the original blowholes in the ingot from which it was made, then it is equally probable that there is some path of escape. Whatever may be the nature of this escape, whether leakage, diffusion, or re-absorption, if we can make part of the gas follow that path and escape, then it seems to me probable that with skill and care we can make the whole of the gas follow that same path.

The first thing is to get the right point of view. If a Martian, uncertain whether the human inhabitants of this earth, namely men, are mortal, sees that, in a battle or railroad accident, some men are killed and others are not, he reasonably infers that all are mortal, and that there is no inherent physical impossibility in annihilating the race. Qualitatively they are mortal. Therefore annihilation depends solely on quantitative considerations and administrative methods, on your ability to apply the known fatal agency to all.

In the same way proof that part of the blowhole gas is expellable is almost mathematical proof that all of it is. Proof that certain blowholes are completely closed is almost

*Mr. E. Von Maltitz, of the Illinois Steel Company, seems to hold that this sealing is hermetical, saying "The action of rolling and stretching the steel will also stretch the blowholes, *without interfering with the contained gas, which will remain in them just as air remains in a partly-filled rubber bag, which is passed to and fro between two rollers, some distance apart.*" (Trans. American Inst. Mining Engineers, XXXVIII, p. 432, 1907. The italics are mine.)

mathematical proof that all are capable of obliteration. Of course, it is no more proof that the particular rolling mill and the particular method of rolling which A, B, or C happens to use is fitted for the task of complete expulsion, than the death of one man is proof to the Martian that he personally has the ability to annihilate the race. The question whether this, that, or the other mill and practice are competent to close blowholes completely is no doubt an important question, but it is not the question which I try to answer. I simply ask the qualitative question as to the capability of the blowholes to be closed, not the quantitative one as to the capability of any individual man or practice to close them.

If their sealing is hermetic, then there is no use in trying to close them. If it is not, then the question of how far they are to be closed, and indeed whether they are to be closed completely, in any individual case is purely one of expediency, to be decided by weighing the cost of closing against its benefit. This I distinctly do not attempt, though I despair of making any important proportion of my readers believe it.

The general attitude has been the opposite of this. Most metallurgists have assured us that blowholes cannot be closed because they have found some in rolled steel, which is exactly as if the Martian should insist that the survival of a handful of men from the annihilation of an army proved that men were immortal and indestructible. The surviving blowholes in rolled steel tell us little of the effacement of their original companions. From our present point of view the question is, not whether any blowholes persist, but whether any cease to exist.

In this paper I consider a certain plate ingot and the boiler plate rolled from it. The initial difference in density between the blowhole-bearing or "porous" parts and the blowhole-less or "compact" parts of that ingot was very great. I ask whether the degree to which that difference has been removed in rolling the ingot into a plate is such as to indicate that part of the initial gas has escaped or at least is no longer present as gas? In a later paper I hope to give the results of a now incomplete microscopic study of the relics of those blowholes which persist in that plate. Incidentally, I point out the bearing of certain familiar facts on this fundamental question.

GENERAL PROCEDURE.

The Ingot and the Slabs.—Vice-President C. L. Huston, of the Lukens Iron and Steel Company, to whom our sincere thanks are chiefly due, cut from a boiler plate ingot three slabs, Top, Middle, and Bottom (T, M, and B), as sketched in Fig. 1. The slabs themselves with their original blowholes are shown in Fig. 3.

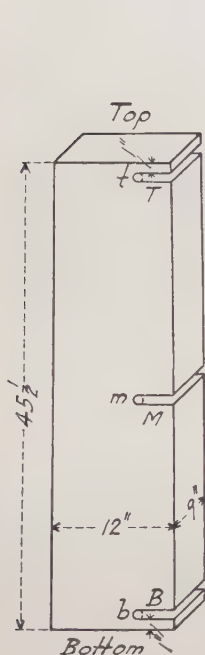


FIG. 1.

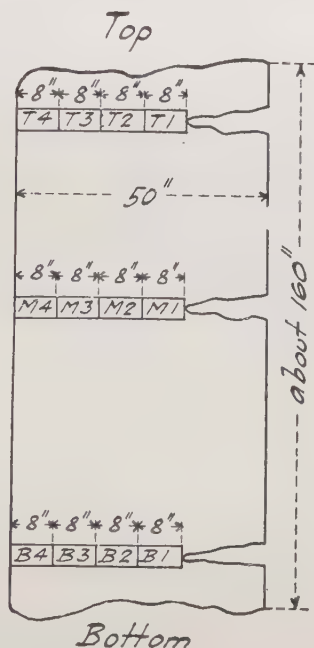


FIG. 2.

The ingot was approximately 9 ins. thick by 12 ins. wide, a little thinner at the top than at the bottom, 45½ ins. long, and weighed 1,150 lbs. It was from the first group poured from a 50-ton basic open-hearth heat.

It contained, according to the maker's ladle test,

Carbon	0.15	per cent.
Manganese	0.34	" "
Phosphorus	0.016	" "
Sulphur.....	0.029	" "

The three slabs, T, M, and B, were cut from the ingot by first drilling three holes, *t*, *m*, and *b*, Fig. 1, right through it, and then sawing into it horizontally with parallel saw cuts from its right-hand edge, as there shown, till these cuts came to the holes *t*, *m*, and *b*.

The middle slab M came from approximately midway of the length of the ingot. The top of the top slab was about 1 in. below the top of the ingot, and the bottom of the bottom slab about 1 in. above its bottom.

The Plate and the Strips.—The ingot was then rolled out into a plate $\frac{1}{2}$ in. thick and 50 ins. wide, and from opposite where the slabs, T, M, and B had been cut, three sets of strips T₁ to T₄, M₁ to M₄, and B₁ to B₄ were cut, all as shown in Fig. 2.

At this point the three slabs and twelve strips came into my possession. Their density was then determined as explained in the Appendix, with the results shown in Table I.

TABLE I.—SPECIFIC GRAVITY OF WHOLE SLABS AND STRIPS.

		Top.	Middle.	Bottom.
Slab	{ By weight and measure	7.3664	7.4695†	7.2268*
	{ Expected density calculated from area of blowholes	7.5758	7.6307	7.4784
Strips	{ No. 1 (see Fig. 2)	7.8940	7.8949	7.8638
	{ No. 2	7.8799	7.8655	7.8634
	{ No. 3	7.8667	7.8673	7.8580
	{ No. 4	7.8612	7.8700	7.8711
	{ Average (weighted)	7.8726	7.8720	7.8641
Specific gravity of strips	{ Average of all strips, 1 to 4 inclusive	1.069	1.054	1.088
Specific gravity of corresponding slabs.†	{ Lightest strip	1.067	1.053	1.087

The most porous and the most compact parts of the middle and bottom slabs from the ingots were then cut out, as sketched in Fig. 3, and their density was determined so that I might learn how much they differed from each other in density; i. e., how

* By weight and measure of volume of slabs.

† Determined by weighing and measuring the fragments into which these slabs were cut.

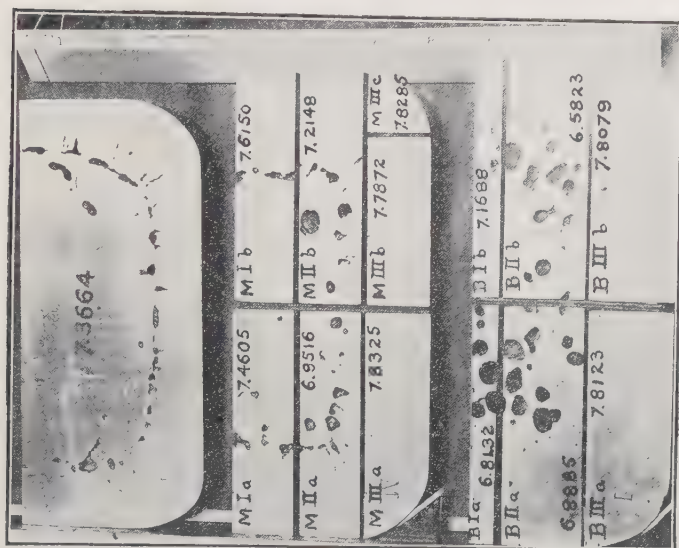


FIG. 3.—The three ingot slabs, showing how they were cut up for density determinations, and their specific gravity.

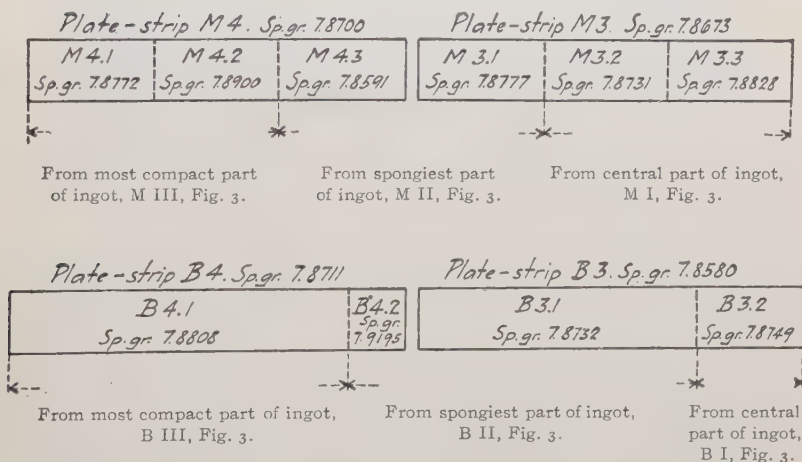


FIG. 4.—Showing manner in which plate strips were cut up for comparing density of initially compact parts with that of initially porous parts.

much porosity the blowholes actually represented. Further, the corresponding parts of the strips which represented in the plate the most porous part of the ingot were cut out, as shown in Figs. 4 and 5, and their density was determined, so that in like manner I might learn what loss of density was actually caused by the remains of the initial blowholes; i. e., how much porosity the remains of those blowholes actually represented.

In this cutting up, each ingot slab was first divided in such a way as to isolate (1) its compact part and (2) its spongy part.

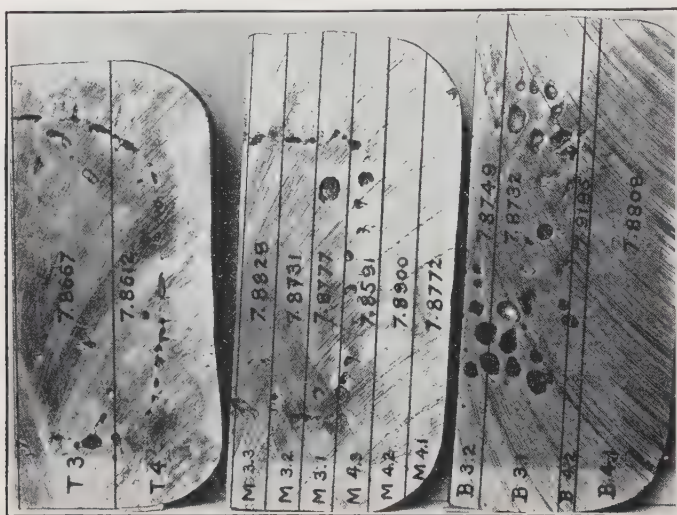


FIG. 5.—Showing position in slabs to which the several fragments of plate-strips correspond, and specific gravity of those fragments.

Then the plate strips were cut up to match; i. e., in such a way as to isolate (1) that part of each strip which represented in position the compact fragment of the corresponding slab, and (2) that part which represented the spongy fragment of the corresponding slab.

The results are given in Table II. For ease of comparison, the data referring to any given fragment or fragments of the plate strips are set vertically under the data referring to those fragments of the ingot slabs which correspond in their position in the ingot

TABLE II.—SPECIFIC GRAVITY OF FRAGMENTS OF INGOT SLABS AND PLATE STRIPS.

Middle (M 3 and M 4 of Fig. 2).				Bottom (B 3 and B 4 of Fig. 2).				Compact ÷ Spongy.					
Position Fragment. (See Fig. 3.)	Central Part, M I.	Spongiest Part, M II.		Outer Compact Part, M III.	Central Part, B I.	Spongiest Part, B II.		Outer Compact Part, B III.	Middle.	Bottom.			
	Position.	Specific Gravity.	Position.	Specific Gravity.	Position.	Specific Gravity.	Position.	Specific Gravity.	Position.	Specific Gravity.			
Piece a.	7.4605	6.9516	7.8325		6.8132	6.8885	7.8123						
" b.	7.6150	7.2148	7.7872		7.1688	6.5823	7.8079						
" c.	.....	.....	7.8285		.....	.....	.....						
Weighted average of a, b and c.	7.5363	7.0855	7.8142		6.9954	6.7328	7.8100		1.103	1.160			
Corresponding Fragments of Plate Strips.	M 3.3	7.8828	M 3.1	7.8777	M 4.2	7.8900	B 3.2	7.8749	B 3.1	7.8732	B 4.1	7.8808	
	7.8781	7.8684	7.8834	7.8749	7.8810	7.8808	1.002	1.000					

to those plate-slab-fragments. Indeed, the purpose of cutting the plate strips into fragments was to get this correspondence. Thus:

Plate strip fragments M 3.3 and M 3.2 (Fig. 5) correspond in position to ingot slab fragments M I, a and b, Fig. 3.

Plate strip fragments M 3.1 and M 4.3 (Fig. 5) correspond in position to ingot slab fragments M II, a and b, Fig. 3.

Plate strip fragments M 4.2 and M 4.1 (Fig. 5) correspond in position to ingot slab fragments M III, a b, and c, Fig. 3.

Plate strip fragment B 3.2 (Fig. 5) corresponds in position to ingot slab fragments B I, a and b, Fig. 3.

Plate strip fragments B 3.1 and B 4.2 (Fig. 5) correspond in position to ingot slab fragments B II, a and b, Fig. 3.

Plate strip fragment B 4.1 (Fig. 5) corresponds in position to ingot slab fragments B III, a and b, Fig. 3.

By comparing these results, (1) the loss of density caused by blowholes in the most porous part of the ingot with (2) the corresponding loss in that part of the plate which represented the most porous part of the ingot, I could learn how far the initial blowholes had been closed up. In doing this I assumed that the ingot had right- and left-hand symmetry, so that the initial distribution of blowholes in the left-hand side of the ingot from which the plate strips came was the same as that in its right-hand side from which the ingot slabs were cut.

DISCUSSION OF RESULTS.

The last two columns of Table II show that the great variations in density which existed in the ingot have been nearly or quite wiped out in rolling. Thus the density of the compact part III of the bottom slab was 16 per cent. greater than that of the porous part II, but in the plate strips this difference has disappeared completely. Indeed, the plate strips representing the porous part of the ingot are very slightly denser than those representing the compact part. Again, the density of the compact part III of the middle ingot slab was 10 per cent. greater than that of the porous part II, but in the plate strips this difference has been reduced to 0.2 per cent., or to one-fiftieth of its original amount.

If, for simplicity, we assume that this relic of the great initial difference in density is due to the presence of corresponding relics

of the initial blowholes, then these relics represent one-fiftieth of the original volume of the blowholes. Of course part of this loss of volume is due to the contraction of the gas itself in cooling from the freezing point, or say 1485°C. , to the temperature at which the rolling ended, or say 700°C. This cooling would reduce the volume of the gas, if at constant pressure, by about one-half,* whereas the actual volume, as calculated above, is only one-fiftieth of the initial, so that according to this the gas ought to be under $50 \div 2 = 25$ times as much pressure in the blowholes at the time the rolling ended as it was at the moment when the freezing ended, on the theory that the whole of the initial gas is still present. As the gas must initially have been under a pressure above the atmospheric in order to be able to push the pasty metal aside and collect in the form of blowholes, this means that the gas in the relics of blowholes at the end of the rolling should have been under a pressure of more than 25 atmospheres, or in other words at more than 350 lbs. per sq. in. above the atmospheric pressure.

Which theory is the more probable, the "persistence" theory that the whole of the initial gas has persisted and is still present in minute blowholes under great pressure, and was present at the end of the rolling under the enormous pressure of 350 lbs. per sq. in.; or the "escape" theory, that part at least of this gas has escaped in one way or another? Let us consider the consequences of these two theories separately.

The Persistence Theory.—Let us consider the distribution of the blowholes as shown for instance in Fig. 3, assuming for

*The volume of gas under constant pressure is proportional to its temperature reckoned from the absolute zero, or -273°C. , so that in this case the volume at 700°C. would be $(700 + 273) \div (1485 + 273)$ or about one-half that at the freezing point, for constant pressure. As to the temperature at which blowholes actually form, I mention parenthetically two facts which tend to show that they form between the solidus and the liquidus curve; i. e., when the metal is in the mushy stage, after the beginning of the selective freezing by the separating out of primary austenite, and before the freezing of the eutectic. The first fact is the observation that much graphite is at times found in certain blowholes in cast iron. (Stead, Proc. Staffordshire Iron and Steel Inst., XXIII, p. 111, 1907-8.) The second is that the sides of blowholes are sometimes coated with the furrows which commonly line the central axial pipe.

It is hard to see how the graphite could migrate to these cavities unless the metal were pretty mobile, and hard to see why it would stay there and not rise to the surface unless the metal were pretty viscous. This indicates, therefore, that the metal, while no longer fluid, was still in a viscous state. The formation of the furrows points in the same direction. My unpublished studies of the furrows in pipes seem to me to prove that they are due to sagging by gravity, and such sagging could occur only in a mushy stage, after freezing had begun but before it had ended, i. e., between the liquidus and the solidus curves.

simplicity that, in the rolling, these blowholes have changed their shape so as to follow the flow of the enclosing metal. The ingot has been drawn out to 3.5 times its original length, widened to 4.17 times its original width, and reduced to one-eighteenth of its original thickness. This would reduce the blowholes at the bottom of the ingot to a layer of pancake-shaped masses at least 3.5 ins. long, about 1.3 ins. wide, and extremely thin, though their exact thickness need not concern us here. Suffice it that under the microscope a few relics do actually appear as such extremely thin pancake-shaped masses. An inspection of Fig. 3 shows us that, in that part of the plate representing the bottom of the ingot, these blowholes would overlap, forming a continuous blowhole-

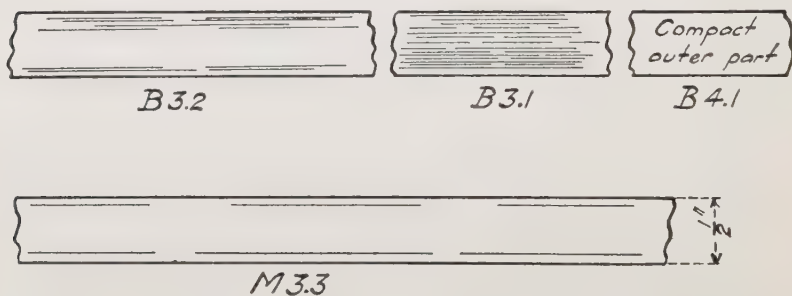


FIG. 6.—Probable arrangement of blowholes in certain plate strips, on the persistence theory that all the initial gas in every blowhole remains undiminished in quantity.

bearing stratum, with several blowholes overlying each other, at a distance of about $\frac{1}{16}$ in. from each face of the plate, somewhat as sketched at B 3.1 and B 3.2 of Fig. 6. In the parts of the plate representing the middle and upper parts of the ingot there would be a like blowhole-bearing layer. Here the blowholes would not in general overlap, but would form a single layer, somewhat as sketched at M 3.3 of Fig. 6. In a plane parallel to the face of the plate and passing through these pancakes, about half the space would be occupied by the pancakes and about half by the solid metal between them. Is it reasonable to suppose that there was such a layer of cavities under a pressure of 350 lbs. per sq. in. when the rolling ceased at 700° C.? Let us consider.

First, why should cavities 3.5 ins. long and 1.3 ins. wide

remain docilely under such pressure, instead of blistering up the whole plate, and thereby reducing the pressure in these pancakes, thus lowering the density of the plate, and in particular restoring an important part of the difference in density which existed in the ingot? What mental picture can we draw which shall reconcile the conception of this layer of pancakes close beneath each face of the plate, with the fact that in the plate the density of the parts which in the ingot were most porous is practically identical with the density of the parts which in the ingot were most compact? How can the gas in the pancakes have remained meekly under this enormous pressure without puffing up the thin layer of metal which overlies it? And, if it has puffed the plate up, how comes it that the density of the initially porous parts now equals that of the initially compact parts?

But a second and still more serious difficulty confronts this theory if we consider the condition of affairs at the end of the first pass, when the metal is very soft and plastic.

Consider the position of the blowholes, and especially the much greater proportion of blowholes in and about the vertical planes AA and BB, of Fig. 7 (*a*), than in and about the intermediate vertical planes such as CC. Now when the ingot begins to be rolled down into a plate, the reduction in thickness should be the same at AA and BB as at intermediate points. The enormous pressure of the rolls will be transmitted to the blowholes, reduced but little because the metal itself is so soft, and will compress them correspondingly. Immediately after the first pass, on the release of the pressure of the rolls, this pressure ought to cause these blowholes to puff up again, all over each face of the plate. Now because the quantity of blowholes in the lines AA and BB is much greater than at intermediate points, a much larger proportion of the reduction should take effect in compressing the gas in these blowholes, by forcing the neighboring metal to flow horizontally into the space which they initially occupy, at AA and BB, than elsewhere. This flow is suggested at D, E, F, and G in Fig. 7 (*b*). Hence, on the release of the pressure as the plate emerges from the rolls, the fact that the volume of the blowholes which thus have to re-expand is much greater at AA and BB than at intermediate points, should cause much more puffing up there than elsewhere, and this should raise a ridge running lengthwise

of the ingot near either edge. If the proportion of blowholes is very small, these ridges might escape observation; but if the quantity of blowholes is anything like as large as that shown in the bottom slab in Fig. 3, this puffing up should be very conspicuous. Though I have watched the rolling of such plates hour after hour and day after day, looking carefully for any peculiarity, I have never noticed such ridges or puffing. I can hardly believe that they should have formed and escaped my notice. Others perfectly familiar with plate rolling inform me that they have never seen them. They certainly ought to thrust themselves irresistibly on our notice when we caliper the plates towards the end of the rolling in order to control its final thickness.

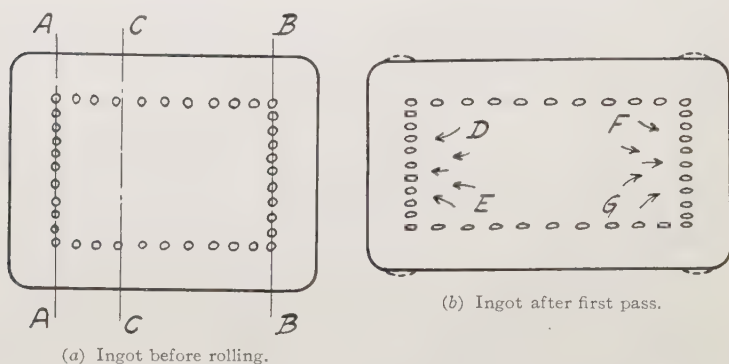


FIG. 7.—Flow of metal and probable puffing into ridges to be expected on the persistence theory.

Again, if such layers of large pancaked cavities ran through-out each and every plate, then they ought to attract great attention, if not in the bending test, because the metal for this is habitually taken from the edge of the plate, outside where the supposed layer of blowholes should end (B4.1 of Fig. 6), then certainly in the punchings. These should flake open. But in fact I am credibly informed that, though the better makers of boiler plates advise their customers to seek for traces of blowholes in these punchings, they are found only to a slight extent, certainly not to the extent implied by the persistence theory, with its layers of ubiquitous broad pancakes.

On all these accounts the persistence theory seems to me to fit the facts extremely poorly, if not, indeed, to be wholly incredible.

The Escape Theory.—The composition of the gases found in the blowholes on boring cold steel suggests that much of the initial gas is no longer present; and the passage of gas into and out of hot iron under familiar conditions is such as to indicate that it may make it antecedently probable that the gas in these blowholes may escape, either by re-absorption, diffusion, or leakage. I will cite four cases.

1. The gases which form the blowholes initially are rich in carbonic oxide; those which are found in the cold metal usually contain but little of this gas and consist chiefly of hydrogen and nitrogen. Hence it is probable that most of this carbonic oxide has disappeared, because it is more probable that the change in the ratio of carbonic oxide to hydrogen and nitrogen has come about by the escape of the first of these gases than by a great increase in the quantity of the two others. To this it may be objected that the carbonic oxide may have escaped not as such, but by oxidizing and carburizing the sides of the blowholes.

But, if iron may thus take up oxygen, why may it not dissolve hydrogen and nitrogen?

2. The hydrogen with which wire becomes charged in pickling is driven out very easily by moderate heating. This makes it probable that this gas can escape readily through the walls of the metal, especially when its exit is favored by the enormous pressure caused by the rolling. The hydrogen in the center of the wire certainly travels, and travels rapidly, to its outside, unaided by pressure.

3. Hydrogen is readily absorbed by hot iron even under moderate pressure. How much more easily should it be absorbed from the blowholes under the enormous pressure which exists in this case?

4. The large quantity of nitrogen which is found in unfired soaking pits, in excess of what seems to have come from the atmosphere, indicates that a steel ingot can give out a large quantity of nitrogen without the assistance of pressure from within to drive it out. How much more readily, then, should the nitrogen be driven out by the great pressure which exists in this case?

SUMMARY.

The theory that all of the initial gas is still present as gas is extremely difficult to reconcile with the uniformity of the density of the different parts of the plate here studied; with the habitual smoothness of plates in rolling; and with the slightness of the lamination found in boiler-plate punchings. On the other hand the difference in composition between the initial gas and that in the cold metal in other steel ingots certainly suggests that much of the initial gas disappears in cooling; and the familiar passage of gas into and out of iron, even without the aid of pressure, makes it easy to believe that, under the enormous pressure in this present case, much of the gas has escaped.

Of course each one must interpret these facts for himself. To me they make it extremely probable that much of the initial gas has disappeared. Whether this has resulted in closing some of the blowholes completely and welding them up, or whether unwelded traces of each and all of them persist, I hope to be able to report later.

If Mr. Huston has succeeded in expelling most of this gas, why is it not possible, when expedient, to expel the whole?

If the blowholes can be closed, can they be welded? That should depend on the stickiness of the steel at the moment when the closing is complete; i. e., on how low the carbon is, and how heavy the reductions at a high temperature are. To me, personally, it seems extremely probable that they can be welded, at least in low carbon steel, from our general knowledge of the conditions. Mr. John Coffin showed that tool steel could be welded by light pressure on passing Ac_3 , say 800°C . Our micrographs show how readily the crystallization of ferrite strikes right across boundaries which at first sight ought to arrest it. The almost complete certainty with which steel skelp is welded, even though its surfaces are drenched with scale, makes it easy to believe that the unoxidized faces of deep-seated blowholes should weld easily if actually forced into contact at a high temperature. And here we should remember that the need of a high temperature in common welding arises, not from absence of stickiness at much lower temperatures, but from the fact that at these lower temperatures the iron oxide is infusible, that hence it cannot be extruded, and prevents our bringing metal against metal.

APPENDIX.

DETERMINATIONS OF DENSITY.

Preparation.—Each piece was trued at the edges by milling, then polished smooth all over, and washed in alcohol.

Density of Plate Strips.—This was determined by the immersion method; i. e., by weighing first in air and second in distilled water, boiled, and cooled off in a closed vessel. The results give the density in vacuo, at t_1° , the temperature of the water used, which in fact lay between 18.0° and 23.7° C. The formula is

$$\text{Sp. Gr.} = \frac{SD}{w} \quad (1)$$

in which S = the true weight in vacuo of the strip, w = the true weight in vacuo of the water displaced by the strip, and D = the specific gravity of the water at t_1° .

The weights actually observed were s , the weight of the strip in air, and s_w , its weight in water.

The apparent weight of the water displaced is

$$w_1 = s - s_w \quad (2)$$

But while it is evident that the buoying action of the water on the strip immersed in it is independent of the atmospheric pressure and is exactly the weight of the water displaced, the apparent weight, s_w , of the strip when in the water has been increased by the lifting action of the air on the brass weights. In other words, the weights needed to balance the immersed strip have to equal not only the net weight of that strip, s_w , but also the lifting action of the air on the weights themselves.

Hence in order to get w , the true weight of the water displaced, we must subtract from s_w , which is the same as adding to w , this lifting action, which is

$$\left(w_1 - \frac{w_1}{8.5}\right) A = 0.882Aw_1 \quad (3)$$

in which 8.5 is the specific gravity of the brass weights and A is the weight of 1 c.c. of air at the temperature and barometric pressure at the time of weighing.

Hence

$$\begin{aligned} w &= w_1 + 0.882Aw_1 & (4) \\ &= w_1(1 + 0.882A), & \text{or from (2)} \\ &= (s - s_w)(1 + 0.882A), & \text{and hence} \end{aligned}$$

$$\text{Sp. gr.} = \frac{SD}{(s - s_w)(1 + 0.882A)} \quad (5)$$

Accurately speaking, a like correction should be made to the observed weight of the strip in air, because when it is weighed both it and the brass weights are buoyed up by the air. But in fact this correction is negligible, because of the slight difference in density between the strips and the weights. This is readily understood if we suppose for a moment that the weights had exactly the same density as the strips. In that case the volume of the weights and of the strips would be identical, and hence the buoying effect of the air on both would be the same. It is only when there is a material difference in density between the substance examined and the weights, and in observations of great nicety, that this correction is needed. Hence in (5) we may substitute the observed weight in air, s , for S , and the formula becomes

$$\text{Sp. Gr.} = \frac{sD}{(s - s_w)(1 + 0.882A)} \quad (6)$$

The Ingot Slabs.—Their weight was determined by weighing in air, their volume by measurement, the thickness by means of a Brown and Sharpe micrometer caliper, and the area of the upper and lower surfaces by means of a planimeter.

It would have been much less accurate to determine their volume by displacement, i. e., by weighing them in water, because the water would have entered many of the blowholes, and thus the volume of water displaced by the slab would have been much less than the volume which I sought, viz., that of the metal proper plus the blowholes.

But as a rough check on the method of weighing and measuring I re-determined the density of five of the most compact pieces cut from the ingot slabs by weighing them in air and water, with the results shown in Table III. The difference between the results given by these two methods was in every case less than

1 per cent., from which I infer that the great differences of from 10 to 16 per cent. in density which I find between the porous and the compact parts of the ingot slabs are in the main true, and that they cannot be referred in any important part to error in the method of measuring.

As a further check I calculated what the density of the three original slabs ought to be in view of the quantity of blowholes they contain, as found by measuring the area of the blowholes on the upper and lower surfaces. In making this calculation I

TABLE III.—RELATION BETWEEN DENSITY OF THE MOST COMPACT PART OF THE INGOT AS FOUND BY MEASUREMENT AND THAT FOUND BY IMMERSION.

		a. By Measure.	b. By Immersion (displacement).	Difference, a - b	Percentage Difference, $\left(\frac{\text{diff.}}{a} \times 100\right)$
Middle Slab	{ M III a..	7.8325	7.7739	0.0586	0.75
	{ M III b..	7.7872	7.8177	0.0305	0.39
	{ M III c..	7.8285	7.7929	0.0356	0.45
Bottom Slab	{ B III a..	7.8123	7.8078	0.0045	0.06
	{ B III b..	7.8079	7.8295	-0.0216	-0.28

assumed that the metal between the visible blowholes had the average density of the plate strips from the most solid part of the ingot, i. e., from its outside. I had further to assume that the volume of the blowholes throughout each slab bore the same relation to the volume of that slab, that the area of the blowholes as measured on the upper and lower surfaces of that slab by means of a planimeter, bore to the total area of those surfaces of the slab. In other words, if

D_e = the expected density of the slab, as inferred from the area of the visible blowholes on its upper and lower surfaces;

D_n = the normal density of the metal between blowholes, taken as equal to the density of the plate strips representing the most compact part of the ingot;

A = the sum of the areas of the upper and lower faces of the slab, and

a = the sum of the areas of the visible blowholes in those faces;

then

$$D_e : D_n = (A - a) : A$$

$$D_n = \frac{7.8834 + 7.8808 + 7.8612}{3} = 7.8751$$

$$D_e = 7.8751 \times \frac{(A - a)}{A}$$

The density thus calculated, given in the second line of Table I, is in every case considerably greater than that found by weighing and measuring. The difference varies from 0.1612 in the middle slab to 0.2516 in the bottom slab. This suggests that, in addition to the visible and measurable blowholes, there is a considerable quantity of minor ones.

The weighings were all made by means of a large balance belonging to the Department of Physics of Columbia University, with which weights as great as 130 lbs. can be determined with an error of two or three units in the fourth place of decimals.

DISCUSSION.

THE PRESIDENT.—This is to me an intensely interesting paper. You know, one of the annoyances of the locomotive firebox is what we call “blisters.” The side of the firebox toward the fire may be subjected at times to as high a temperature as 2500° or possibly 3000° F., while the side that is next to the water is at a temperature of from 300° to 400° F., depending upon the pressure that is carried. Now the very high temperature on the one side and the very low temperature on the other means that there must be an enormous amount of heat transmitted, or else there is going to be trouble; and if there is a cavity not welded up, then we get a blister on account of the failure of the heat transmission at that point. The President.

MR. J. P. SNOW.—When we consider the base of steel rails, we find little seams which are not parallel with the surface as they are in a plate, but vertical. On the upper portion of the base near the junction with the web, these little seams are parallel to the surface; but in the bottom of the base they are vertical. Now whether they are the result of blowholes or something else, I will not undertake to say; but from what Mr. Howe has said it seems to me that it is fair to suppose that they are the result of blowholes which were not welded. Mr. Snow.

MR. R. W. HUNT.—Perhaps those who are familiar with the steel business will recall that the maker of tool steel invariably puts his ingots through what he calls the welding process; heating them carefully and putting them under a comparatively heavy hammer, and endeavoring to weld up the blowholes before drawing the ingot into commercial shapes. In making boiler plate and rails I think manufacturers as a rule do not take that precaution, which perhaps might account for some of the bad things we find. We should carefully distinguish those blowholes from the defects caused by occluded pieces of slag which have been left in the steel and which will cause defects that no welding will eliminate. Mr. Hunt.

Mr. Thackray. MR. G. E. THACKRAY.—Some years ago an effort was made to produce tool steel by the open-hearth process, at a small works in Ohio, and with small ingots made as stated, they had considerable success. At that time I tried and examined some of the tool-steel bars made by that process, and found that for many uses it was as good as some crucible steel, while in other respects it failed to stand up to its work, presumably on account of unwelded blowholes that were in the ingots; the opportunity not having been given in the open-hearth process to dead-melt it to such an extent as to eliminate all the gases before pouring. In reply to the criticism which has just been made to the effect that the makers of steel do not attempt to weld up the blowholes, I wish to say that those who are engaged in that business would not subscribe to the statement for the reason that all steel ingots are carefully and slowly heated to a very high temperature and in rolling these ingots into blooms or billets they are first given very heavy drafts or reductions with the intention of welding up the cavities and blowholes, if they exist. Great care is given to the heating to see that the ingots are at the proper temperature, not only on the outside, but throughout their body. Of course, with the larger sizes of steel ingots, it is impossible to have the heat exactly uniform throughout, but nevertheless the attempt is made and, as the result generally proves, with great success.

Mr. Hunt. MR. HUNT.—There is no special part of the process of producing rails or plates which can be designated a "welding process." The ingot is heated to a degree which will permit the production of its finished product at that heat, but not to accomplish any special welding. It is then heated again, and the further process of rolling continued. The tool-steel maker uses a flux upon the steel in his welding process, and exercises his best judgment and skill upon each ingot as a separate proposition. The result depends upon the skill of the workman.

Mr. Huston. MR. C. L. HUSTON—The superficial defects, streaks, and seams that occur in the process of welding I should hardly suppose could penetrate very deeply into the steel. Of course a section of tool steel is almost universally small, and a small amount of penetration would affect a large percentage of the tool steel; whereas, in the sizes that we deal with in making boiler plate and rails, the proportionate amount of penetration that could be obtained by

using a flux on the outside would become insignificant. I think **Mr. Huston.** it quite evident from the number of little cavities that we can discover by a nicking test on an ingot, that only a very small proportion of these are left after rolling. In practice the examination for cavities is usually made from a sample taken near the sheared edge, which would probably represent the best part of the ingot.

MR. W. A. BOSTWICK.—I think one of our recent speakers **Mr. Bostwick.** was unfortunate in his simile, in likening a 100-lb. crucible ingot to the ingots used in the manufacture of boiler plate, which run several thousand pounds in weight. Mr. Howe, in connection with his recent work, states that he had some experience a number of years ago which shows that a blowhole which has not oxidized will weld to such an extent that it cannot be found in the finished material. Whether or not the gas has been driven out, or driven in, or what has become of it, I do not know; but the fact is that in the finished product there will be no trace found of the blowhole provided you have kept the oxygen away and prevented the formation of a film of oxide.

MR. H. M. HOWE.—Perhaps I did not make the distinction **Mr. Howe.** as clear as I should have. In what I said about closing blowholes, I meant driving the gas out of them. I did not mean the driving out of them of oxide or slag. If you have oxide or slag in the hole, it is going to stay there, because it is not gaseous and hence cannot escape through the walls.

MR. J. A. MATHEWS.—In regard to welding tool-steel ingots, **Mr. Mathews.** I would say that this practice is rather unusual to-day. Most of the tool-steel ingots do not require welding. In the tool works that I have been connected with I have never seen a welding fire. We weld absolutely no tool steel. Ingots when properly melted appear to be free from blowholes, or, if containing them, they close up readily on cogging. Personally, I should look with suspicion upon the melting practice of any crucible plants whose ingots require welding.

THE PHYSICAL QUALITY OF STEEL WHICH HAS BEEN SUBJECTED TO COMPRESSION DURING SOLIDIFICATION.

BY BRADLEY STOUGHTON.

The purpose of compressing steel during the period of its solidification is to prevent the occurrence of defects which are developed at this time either by the metal or the substances dissolved in it, and which, in the careful manufacture of steel for structural material, rails, wire, plates, sheets, tools, etc., are the least capable of accurate control. So far as the record shows, it has not been denied even by those who have adopted the compression process, that precautions observed during the chemical process of manufacture will greatly lessen the liability to some of these defects, such as blowholes and segregation; that subsequent discards if sufficiently extensive will remove the whole or a greater part of some of them, such as segregation and pipes; or that mechanical treatment will usually remedy, in part at least, the remaining ones, namely external cracks and ingotism. It is apparently their belief, however, that occasionally, in spite of the usual precautions in ordinary practice, one or more of these defects may be present in the finished product without the knowledge of the manufacturer or the consumer, and that careful compression during this critical period will prevent some of them and materially lessen the others, thus providing a further safeguard against the occurrence of remnants of these defects in the finished material.

Blowholes.—The opinion of those who have investigated the soundness of compressed steel, either from the scientific standpoint or during practical experience with the process, seem to be in favor of the claim that liquid compression will lessen the size of the blowholes, if it does not prevent them altogether.* In References Nos. 2, 3, 4, 5, 7, and 10, this subject is discussed at some length and photographs reproduced of split compressed ingots

*See Howe, Ref. 1, p. 161; Harbord, Ref. 8, p. 498; Gledhill, Ref. 5, p. 36; Beardmore, Ref. 5, p. 38; Osann, Ref. 7, pp. 1611-2.

which are stated to be sound throughout, and apparently are so, thus corroborating this favorable opinion. Opposed to it is one example, that of a nickel steel ingot compressed by the Harmet process and tested by Howard.* Two photographs of this ingot show evidence of the remnants of blowholes, which is confirmed by the behavior of the test pieces in tension. However, there is collateral evidence tending to show that the compression of this ingot was not correctly performed, either because the presence of the nickel so changed the melting point of the steel as to require a different application of compression than that usually employed, or for some other reason which does not appear. We shall discuss this ingot more fully at a later period.

Compressed steel is relieved of one liability to blowholes to which uncompressed steel is subject, on account of the common practice of steel makers, in order to lessen the volume of the pipe, of intentionally allowing a few blowholes to form but with precautions intended to insure their being located in a deep-seated and therefore comparatively harmless position.

Pipes.—There has been no dispute, we believe, as to the fact that compression during solidification, if properly applied, will completely close up the contraction cavity in the top of the ingot and may even, if desired, cause the ingot to be overfilled, i. e., cause the plastic metal to overflow and form a bulge on the top. Indeed, the chief claim for the compression process in its commercial aspect is based on saving the expense of remelting 20 to 35 per cent. of the top of uncompressed ingots because of the cavity in that portion. It is true that the crop in normal practice is habitually only 5 to 10 per cent., but there is not wanting evidence to show that this practice does not always remove the whole of the piped metal, however sound the bloom may appear to the eye due to the closing together of the sides of the cavity by the action of the shears.

The correct accomplishment of compression involves applying it neither too early nor too late in the period of solidification. If the former, the top of the ingot will be closed before the interior has solidified, and subsequent contraction will produce a narrow cavity some distance from the top of the ingot. If the latter, the cavity will already have formed and the pressure applied will not

*See Ref. 6, p. 314.

be sufficient to weld the solid sides together. In the practical manipulation of the compression processes, however, the progress of solidification may be readily observed and the compression controlled so as to produce an entirely pipeless ingot.

Segregation.—The last part of the metal to solidify is the richest in impurities, and it is this part which is forced by compression during solidification into the upper part of the ingot which is removed by cropping. The extent to which segregation will be lessened by this operation will therefore depend upon the extent of the lifting effect. Howe says:*

To sum this up, the beneficial lifting effect on the segregate should be the greatest in William's system, which compresses the ingot chiefly in the middle of its length; it should be the least in Whitworth's system, which compresses the ingot more at its top than elsewhere; and it should be intermediate in the systems of Illingworth and Harmet, which compress the ingot equally in all parts of its length.

Analyses given by Harmet† indicate that the segregation in three given compressed ingots is very slight throughout 90 per cent. of their length, in carbon, sulphur and phosphorus. The analyses are significant, but in view of the uncertainty of locating segregation in ingots, they are hardly sufficiently extensive to show conclusively that segregation in compressed ingots may not sometimes occur. He uses for comparison the analyses of two uncompressed ingots including only about the lower two-thirds or three-fourths of their length, in which the variations in carbon were twice as great as the largest variations in any of the compressed ingots. The variations in sulphur were slightly greater than in the compressed ingots and the variations in phosphorus were about the same in the uncompressed as in the compressed ingots.

Analyses of compressed ingots given by Capron‡ also show a very slight variation in the sulphur and phosphorus, except for the upper 10 per cent. of the ingot, which in one case is slightly low in sulphur, and in two other cases is 30 to 100 per cent. high in that element. As the greater part of this upper portion would be

*See Ref. 9, p. 265.

†See Ref. 4, pp. 198 and 200.

‡See Ref. 5, pp. 32 and 34.

cropped off in practice, the analyses may be said to be as uniform as need be required for all that part of the ingot which is to be used.

External Cracks.—External cracks may be produced either by the contraction of the metal in the mold, by the bursting open of surface blowholes during the rolling of the ingot, or by tearing the skin of the ingot during rolling because of the tenderness of the metal resulting from its undisturbed crystallization from the liquid state. - Compression during solidification will lessen the liability to these cracks because of the pressure put upon the metal while in the plastic condition. Referring especially to the Whitworth fluid compression process, Howe says:*

To sum up, in proper hands the liquid compression of large masses, if powerful enough, according to our present evidence, does prevent pipes, blowholes and cracks almost completely, so that we may avoid the expense to which we are put in common practice of remelting from 5 to 35 per cent. of the weight of each ingot on account of unsoundness.

When ingots are rolled, most of the external cracks disappear, especially if a wash heat be given to the bloom before the rolling is finished, or if the blooms, slabs or billets are allowed to cool and the defects chipped out of them before they are reheated for the final mechanical operations. Nevertheless, there is always a certain percentage of external cracks which develop into flaws in the finished material and cause them to be rejected or relegated to the second class.

COMPARATIVE PHYSICAL TESTS OF COMPRESSED AND UNCOMPRESSED STEEL.

Since compression of steel ingots first came into prominent notice, now more than twenty years ago, there has existed a difference of opinion among steel makers as to the alleged superiority of the physical qualities of the compressed steel over those of the steel which has been cooled in the ordinary way. In order to throw some light on this subject, I have collected all the comparative tests that I could find from various sources, and, as these are now brought together for the first time, as far as I know, they are included herewith in Tables I to VII. However, no tests are

*See Ref. 1, p. 161.

TABLE I.—TENSILE TESTS OF UNFORGED INGOTS.

Set No.	POSITION IN INGOT.	UNCOMPRESSED INGOTS.				COMPRESSED INGOTS.			
		Ultimate Strength, lbs. per sq. in.	Elastic Limit, lbs. per sq. in.	Elongation in 4 ins., per cent.	Reduction of Area, per cent.	Ultimate Strength, lbs. per sq. in.	Elastic Limit, lbs. per sq. in.	Elongation in 4 ins., per cent.	Reduction of Area, per cent.
1*	Bottom Row..	67,300	25,300	14.83	8.46	61,300	23,400	17.29	14.45
	Second "	66,500	25,500	10.93	5.24	65,400	23,300	17.43	10.55
	Third "	65,800	25,300	8.87	4.47	67,100	25,100	14.16	9.81
	Fourth "	62,600	24,000	5.50	2.31	64,700	26,800	8.46	4.39
	Fifth "	64,800	24,500	3.65	1.37	64,300	26,600	8.67	5.01
	Sixth "					67,100	27,400	9.32	4.57
	Top "					73,100	27,000	12.21	6.54
2*	Bottom Row..	66,200	26,300	12.44	6.56	60,400	21,600	13.71	8.51
	Second "	66,000	25,100	10.07	4.87	68,200	24,600	16.55	9.94
	Third "	69,200	26,300	8.87	4.35	68,400	26,300	12.40	7.05
	Fourth "	68,000	25,700	5.17	1.74	70,900	27,200	12.83	6.57
	Fifth "	51,300	24,600	2.02	0.52	67,700	27,400	10.13	5.97
	Sixth "					73,100	30,200	11.91	5.33
	Top "					62,800	25,700	11.63	9.62
3†	Bottom Row..	56,000	26,600	14.0	15.3	60,700	32,900	11.5	11.3
	Second "	40,800	23,300	4.3	4.3	50,300	23,700	10.8	11.3
	Third "	34,100	24,600	4.2	4.3	51,400	23,700	11.0	12.6
	Fourth "	38,000	23,800	5.0	8.5	50,300	23,700	11.5	17.9
	Fifth "	24,200	23,800	2.0	2.8	53,000	24,200	11.0	12.7
	Sixth "	Defective Test Piece				55,100	28,000	8.2	12.6
	Seventh "					53,200	24,700	6.0	7.1
	Eighth "					54,300	28,000	7.8	11.2
	Top "					55,000	30,000	5.0	4.3
4†	Bottom Row..	60,900	39,400	13.0	16.5	63,700	40,800	16.0	15.3
	Second "	49,300	37,000	6.3	7.1	61,700	39,500	13.0	16.7
	Third "	Defective Test Piece				50,400	37,000	5.5	11.3
	Fourth "	41,800	37,000	4.0	4.3	57,900	38,000	12.0	15.3
	Fifth "	25,600	25,600	0.0	0.0	59,900	39,000	12.0	17.9
	Sixth "	Defective Test Piece				61,900	38,000	10.0	11.3
	Seventh "					59,900	38,000	8.0	8.5
	Eighth "					61,900	39,000	9.0	15.3
	Top "					62,800	39,800	8.0	8.5
5†	Bottom Row..	51,100	43,400	6.5	12.7	61,900	42,300	20.0	28.0
	Second "	52,100	41,800	6.6	9.9	59,900	41,300	12.3	25.5
	Third "	Defective Test Piece				61,900	42,800	13.5	20.6
	Fourth "					60,900	40,400	15.0	25.5
	Fifth "					63,700	42,800	12.5	17.9
	Sixth "					62,700	43,700	13.5	17.9
	Seventh "					64,700	43,200	9.5	12.5
	Eighth "					66,600	45,100	11.0	11.3
	Top "					62,700	44,100	12.0	17.8
6‡	Bottom.....	116,100	103,700	8.0	16.2	104,500	101,800	5.0	12.7
	"	100,300	94,700	5.0	14.3	114,100	103,700	7.0	20.0
	"	103,200	97,500	6.5	7.6	117,100	99,000	11.0	44.0
	Middle	103,200	99,400	4.5	10.9	119,900	101,800	7.0	16.2
	"	87,500	87,500	2.0	12.7	116,200	101,300	6.0	19.8
	"	89,000	89,000	2.3	7.7	118,300	101,300	7.2	17.9
	Top	Defective Test Piece				100,300	100,300	3.0	6.1
	"					117,300	106,800	7.0	10.9
7§	Ingot Skin....	65,600		19.0§		66,300		21.0§	
	8§ Ingot Center.	43,900		4.0§		58,000		9.0§	

* Each test in this set represents the average of seven tests. The carbon in the compressed ingot was 0.39 per cent.; that in the uncompressed ingot was 0.50 per cent. † Set 1 consists of tests from pieces cut longitudinally of the ingot; set 2 of tests from pieces cut transversely of the ingot. See Ref. 2, Greenwood.

‡ These tests are all from Ref. 3. Set 3 comprises tests of pieces in their natural condition; set 4, after heating to 1000° C.; set 5, after heating to 1000° C., then reheating to 860° C., quenching and reheating to 775° C.

§ Set 6 is from Ref. 4. Before the test pieces were cut from the top of the uncompressed ingot, 28 per cent. was cut off.

§ Sets 7 and 8 are from Ref. 5. The elongation shown is the percentage in 3 ins.

included (with one exception to be explained shortly) unless they comprise tests of both compressed and uncompressed steel, otherwise substantially alike as to grade and manufacture, because it is obvious that this is the only form of evidence which can be accepted as conclusive. Unfortunately, the amount of data is not great, but, such as it is, we shall perhaps be able to

TABLE Ia.—AVERAGES FROM TABLE I.

Set No.	UNCOMPRESSED INGOTS.				COMPRESSED INGOTS.			
	Ultimate Strength, lbs. per sq. in.	Elastic Limit, lbs. per sq. in.	Elongation in 4 ins., per cent.	Reduction of Area, per cent.	Ultimate Strength, lbs. per sq. in.	Elastic Limit, lbs. per sq. in.	Elongation in 4 ins., per cent.	Reduction of Area, per cent.
1	65,400	24,900	8.76	4.41	66,200	25,700	12.51	7.90
2	64,200	25,600	7.91	3.61	67,400	26,150	12.74	7.54
1 and 2	64,800	25,300	8.34	4.01	66,800	26,700	12.63	7.74
3	38,620	24,420	5.9	7.4	53,700	26,544	9.2	11.2
4	44,400	34,750	5.8	7.0	60,000	38,800	10.4	13.3
5	51,600	42,600	6.6	11.3	62,800	42,850	13.3	19.7
6	99,883	95,300	4.7	11.6	113,867	102,500	7.1	21.3

TABLE Ib.—AVERAGE PERCENTAGE VALUES OF COMPRESSED INGOTS IN TERMS OF UNCOMPRESSED.

Set No.	Ultimate Strength.	Elastic Limit.	Elongation in 4 ins.	Reduction of Area.
1 and 2	103%	106%	151%	193%
3	139 "	109 "	156 "	160 "
4	135 "	112 "	179 "	190 "
5	122 "	101 "	201 "	174 "
6	114 "	107 "	151 "	184 "
7	101 "	.....	111 "*"	.....
8	132 "	.....	225 "*"	.....

form from it some opinion of the relative merits of the conflicting claims.

In Table I are shown tensile tests of compressed and uncompressed ingots. As we might expect, the tests of compressed ingots are generally better than those of the ingots cooled in the ordinary way, for it is under these circumstances that liquid compression has the best opportunity to show its influence in

* Elongation in 3 ins.

preventing ingotism and improving the structure of the metal. The ultimate strength of the compressed metal averages from 3 to 39 per cent. greater than that of the uncompressed metal; the elastic limit, from 1 to 12 per cent. greater; the elongation, from 11 to 125 per cent. greater, and the reduction of area from 60 to 93 per cent. greater (see Tables Ia and Ib).

There is not wanting testimony, however, to indicate that compression is not always successful in producing ingots of good strength and ductility, and the Harmet steel ingot, whose qualities are shown in the tests in Table II, is an example of the opposite

TABLE II.—HARMET NICKEL-STEEL INGOT.
(Reference No. 6.)

Ultimate Strength, lbs. per sq. in.	Elastic Limit, lbs. per sq. in.	Elongation.		Reduction of Area, per cent.	Remarks.
		Per cent.	In — ins.		
58,553		6.1	6 or 10	10.7	Average of 60 tests from upper half of ingot.
62,547		7.9	10	15.1	Average of 66 tests from lower half of ingot.
60,645		7.1	....	13.1	Average of 126 tests.
77,970	46,250	23.2	6	55.2	Average of 4 tests from upper half of ingot; forged slightly and annealed.
25,100					Longitudinal from center at middle of upper half.
20,500					Longitudinal from middle of lower half.

kind. This steel contained 0.19 per cent. carbon, 0.98 per cent. manganese, 3.30 per cent. nickel and 0.032 per cent. phosphorus, and, although we have no tests of an uncompressed ingot of like composition and manufacture with which to compare it, the results are not such as to commend liquid compression if its advantages rested on them alone. The ingot was compressed for 5 hours and 18 minutes, yet it contained structural defects and lines of unsoundness. The lines of structural unsoundness developed into open cracks in the tension tests making their appearance under comparatively early loads and locating the place of final rupture. Specimens which had these defects parallel, or nearly so, to their stems gave results above those in which the

defects were more nearly normal to the direction of the pulling loads.*

In view of the sound ingots known to be obtained time after time by the compression process, we may first suppose that the compression operation was improperly applied to this ingot. From this viewpoint the results prove, not that liquid compression if properly applied gives poor results, but that one process of compression at least may not always be applied so as to do the work that is expected of it. In other words it shows, if we have diagnosed this case correctly, that the compression process, like other steps in the steel-making operation, is open to occasional failure. It may well be, however, that we have not stated the case correctly above and that the unsoundness of this ingot is really due to the fact that the metal was very wild owing to faulty manufacture, and that liquid compression is not capable of curing such an extreme case of unsoundness. Whichever explanation is accepted as the most likely one, these Watertown tests throw useful light on the subject under discussion.

The results of Table I show that liquid compression actually does prevent ingotism to some degree, and this is the more evident because the toughness of the metal is increased even more than its strength. Any difference in the Greenwood tests due to the difference in carbon between the compressed and uncompressed ingots may be offset by the circumstance that the average results of the compressed ingot are superior both in strength and ductility to those of the uncompressed steel. The improvement in toughness shown in Table I is confirmed by the impact tests in Table III, where the compressed metal has a ductility about 30 per cent. better than that of the uncompressed steel, and we may conclude from all the evidence presented that compression does prevent some of the defects developed during crystallization and improves the physical quality of steel up to this point in its manufacture.

But even if it be admitted that the compressed ingots are stronger and tougher than the others, it is proper to observe that this is not a true practical criterion of ultimate superiority, since ingots are not ordinarily used in service until work has been put upon them which would have the effect of remedying some defects

*See Ref. 6, p. 314.

TABLE III.—IMPACT TESTS ON UNFORGED INGOTS.
(Reference No. 4.)

Position in Ingot.	UNCOMPRESSED INGOTS.				COMPRESSED INGOTS.			
	Broke at n th Blow. n.	Angle of Breaking, degrees.	Deflected D mm. at m th Blow.		Broke at n th Blow. n.	Angle of Breaking, degrees.	Deflected D mm. at m th Blow.	
			D.	m.			D.	m.
Bottom	19	105	.....	.....	Broke in press	92	33	20
"	2	180	.....	.....	8	148	.....	20
"	4	175	.....	.....	Broke in press	90	31	20
Middle	2	180	.....	.....	20	113	.....	.....
"	2	180	.....	.....	Broke in press	98	32	20
"	1	180	.....	.....	13	135	.....	.....
Top	1	180	.....	.....	13	150	.....	.....
"	Defective	Test Piece.	.....	.....	12	142	.....	.....
" .....	"	"	.....	.....	18	102	.....	.....
Bottom	Broke in press	79	32	20				
"	3	160	.....	.....				
"	5	152	.....	.....				
Middle	8	141	.....	.....				
"	6	148	.....	.....				
"	5	154	.....	.....				
Top	Defective	Test Piece.	.....	.....				
"	"	"						
"	"	"						
Average .....	.....	151*	.....	.....	.....	119*	.....	.....

*Reciprocal of percentage of compressed to uncompressed ingots = 130 per cent.
Bars, 20 X 20 mm. Weight of drop, 18 kilograms. Height of drop, 1.10 meters.

TABLE IV.—TENSILE TESTS OF FORGED STEEL.

Set No.	Position in Ingot.	UNCOMPRESSED INGOTS.				COMPRESSED INGOTS.			
		Ultimate Strength, lbs. per sq. in.	Elastic Limit, lbs. per sq. in.	Elongation in 4 ins., per cent.	Reduction of Area, per cent.†	Ultimate Strength, lbs. per sq. in.	Elastic Limit, lbs. per sq. in.	Elongation in 4 ins., per cent.	Reduction of Area, per cent.†
9*	Bottom.....	90,900	56,200	16.5	43.6	105,600	88,500	14.3	79.5
	".....	105,500	85,600	12.5	66.3	102,700	82,600	13.0	57.4
	".....	99,300	73,200	13.0	70.2	106,500	86,500	15.0	83.0
	Middle.....	102,100	85,300	12.2	59.7	103,200	82,500	13.2	93.2
	".....	104,500	84,600	10.0	21.9	104,500	82,600	9.0	36.8
	".....	108,100	84,900	7.0	22.1	91,300	61,900	12.0	44.0
	Top.....	87,500	.....	2.0	112.7	Defective Test Piece.			
	".....	65,600	.....	1.0	4.5	90,000	60,900	9.5	29.8
	".....	Defective Test Piece.				99,400	67,400	13.5	71.9
	Bottom.....	Defective Test Piece.							
	".....	109,400	90,300	13.2	90.4				
	".....	104,500	85,000	14.5	86.7				
	Middle.....	103,100	82,500	13.2	65.6				
	".....	84,300	.....	16.0	68.8				
	".....	103,700	84,600	11.0	57.4				
	Top.....	Defective Test Piece.							
	".....								
	".....								
10*	Bottom.....	90,000	57,200	15.8	56.8	115,800	97,400	10.8	44.4
	".....	91,900	59,000	16.0	68.8	114,100	94,200	11.0	51.8
	".....	109,600	86,200	10.2	29.8	114,100	94,200	11.2	60.3
	Middle.....	Defective Test Piece.				118,100	98,000	12.0	66.3
	".....					112,200	90,300	11.0	54.6
	".....					114,100	97,100	9.0	30.1
	Top.....	95,600	61,700	13.0	34.8	120,000	93,700	9.0	34.2
	".....	81,500	56,200	7.0	34.2	119,000	99,400	9.5	48.7
	".....					116,200	98,500	5.5	46.1
	Bottom.....	100,800	75,200	11.0	51.8				
	".....	109,400	94,200	7.0	.....				
	".....	88,500	57,000	10.5	12.7				
	Middle.....	91,400	66,600	17.0	98.3				
	".....	92,200	56,000	17.0	102.4				
	".....	Defective Test Piece.							
	Top.....								
	".....								
	".....								
11†	.....	70,300	.....	25.0§	.....	67,700	.....	26.0§	.....
12	.....	69,400	.....	24.0§	.....	68,100	.....	24.0§	.....
13	.....	69,400	.....	26.0§	.....	69,200	.....	25.5§	.....
14	.....	68,600	.....	24.0§	.....	67,700	.....	24.5§	.....

* Sets 9 and 10 are tests cut from blooms. Ref. 4.

† Test 11 is of an ingot compressed and rolled direct into plate, compared with an ingot cogged and then rolled into plate. Longitudinal test piece from top of ingot.

Test 12 is similar to 11, but transverse test piece.

Test 13 is a longitudinal test piece from the bottom end of ingot; otherwise like 11.

Test 14 is a transverse test piece from bottom end of ingot; otherwise like 11.

Tests 11 to 14, Ref. 5.

‡ The percentage of reduction of area is obtained by the formula: $\frac{S-S'}{S}$.

§ Percentage of elongation in 3 ins.

which compression if properly applied would prevent in part at least. In other words the question resolves itself into this: Is the cure effected by mechanical treatment alone as complete as that due to the combination of part prevention by compression followed by the same mechanical treatment? Referring now to Table IV we find that four blooms shown therein have been rolled direct from the ingot without compression, and after 28 per cent. has been cropped from the top of them, tests have been cut from the remainder. These are compared with tests cut from two blooms

TABLE IVa.—AVERAGES FROM TABLE IV.

Set No.	UNCOMPRESSED INGOTS.					COMPRESSED INGOTS.				
	Ultimate Strength, lbs. per sq. in.	Elastic Limit, lbs. per sq. in.	Elongation in 4 ins., per cent.	Reduction of Area, per cent.		Ultimate Strength, lbs. per sq. in.	Elastic Limit, lbs. per sq. in.	Elongation in 4 ins., per cent.	Reduction of Area, per cent.	
9	97,580		10.9	59.2		100,400	76,610	12.4	62.0	
10	95,090	66,930	12.5	54.4		115,960	95,870	9.9	48.5	
9 and 10	96,500		11.6	56.6		108,590	86,800	11.1	54.8	
11 to 14	69,425		24.8*			68,175		25.0*		

TABLE IVb.—AVERAGE PERCENTAGE VALUES OF COMPRESSED INGOTS IN TERMS OF UNCOMPRESSED.

Set No.	Ultimate Strength.	Elastic Limit.	Elongation in 4 ins.	Reduction of Area.
9	103%		114%	105%
10	122 "	143%	79 "	89 "
9 and 10	113 "		96 "	104 "
11 to 14	98 "		101 " *	

cogged from compressed ingots of which 5 per cent. of the top has been cropped. The average of the two comparisons shows an increase of 13 per cent. in the tensile strength of the liquid compressed steel, with a decrease of 4 per cent. in the percentage of elongation, and an increase of 4 per cent. in the percentage of reduction of area (see Tables IVa and IVb). In one comparison the elastic limit is indeterminable; in the other the compressed steel shows a superiority of 43 per cent. These results, so far as they go, tend to show that the compressed steel is better in strength

* Elongation in 3 ins.

TABLE V.—IMPACT TESTS OF BLOOMS FORGED FROM INGOTS.
(Reference No. 4.)

Position in Ingot.	BLOOMS FROM UNCOMPRESSED INGOTS.			BLOOMS FROM COMPRESSED INGOTS.		
	Broke at n th Blow. n.	Angle of Breaking, degrees.	Deflected D mm. at m th Blow.		Broke at n th Blow. n.	Angle of Breaking, degrees.
			D.	m.		
Bottom.....	Broke in press	0	31	20	Broke in press.	67
"	"	45	29	"	"	48
"	"	25	34	"	"	52
Middle.....	"	23	31	"	"	60
"	"	30	28	"	"	27
"	"	88	32	"	"	63
Top.....	5	161		"	"	72
"	2	170		"	"	54
"	6	155		"	"	27*
Bottom.....	Not broken in press		30†	20		0
"	"		31†	"		
"	"	39	29	"		
Middle.....	"	69	27	"		
"	"	33	30	"		
"	"	37	31	"		
Top.....	1	180		"		
"	1	180		"		
"	1	180		"		
Bottom.....	Broke in press	45	40	20	Broke in press.	70
"	"	58	38	"	"	91
"	"	36	41	"	"	35
Middle.....	"	61	40	"	"	48
"	"	61	38	"	"	32
"	"	48	40	"	"	31
Top.....	"	50	34	"	"	85
"	"	78	37	"	"	70
"	"	64	43	"	"	31
Bottom.....	"	80	31	"	"	34
"	"	0	40*	"	"	91
"	"	44	34	"	"	32
Middle.....	"	0	37*	"	"	68
"	"	0	38†	"	"	91
Top.....	Not broken in press	69	40	"	"	31
"	"	43	34	"	"	34
"	"	78	34	"	"	91
"	"	50	36	"	"	32
Averages.....		63†				58†

* Bent double before breaking.

† Bent double without breaking.

‡ Reciprocal of percent of compressed to uncompressed ingots = 109 per cent.
Bars, 20 X 20 mm. Weight of drop, 18 kilograms. Height of drop, 1.10 meters.

than, and approximately equal in ductility to the uncompressed material, but further data are needed to support a strong conclusion in favor of superiority.

Some data contributing toward this end are shown in Table V, where the impact tests on blooms from compressed ingots are seen to have on an average about 9 per cent. more ductility than

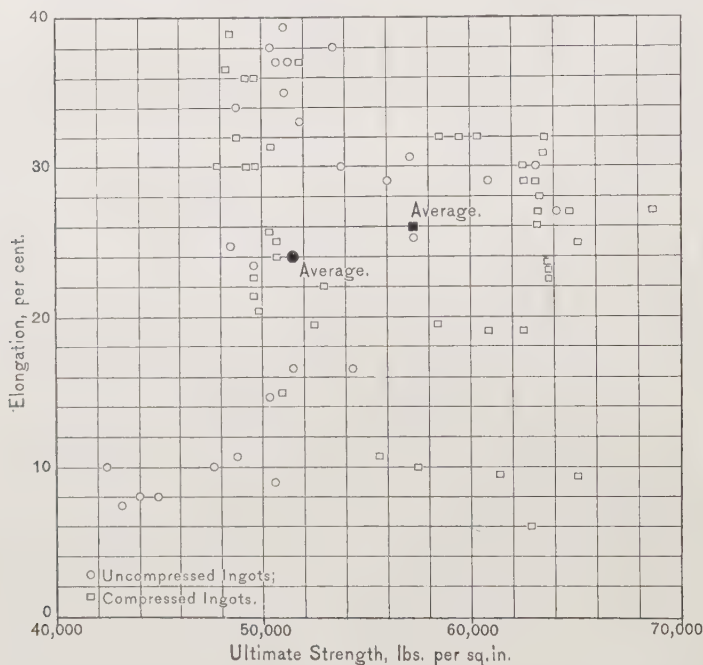


FIG. 1.—Tensile tests of bars, angles, etc., forged from compressed and uncompressed ingots respectively.

those from uncompressed ingots. The tests of the compressed steel are also more uniform in character than those of the uncompressed steel, which vary all the way from pieces that bent double without cracking to those that broke at the first blow without taking any permanent set.

Capron asserted* "that the compressed ingot is at least equal to steel that has been forged or cogged." But the results

*See Ref. 5, p. 33.

he afterwards gave in support of this assertion, shown at the bottom of Table IV, are not sufficiently extensive to be conclusive. We think that so advanced a statement as this requires very complete verification before being accepted. His results add hardly anything either for or against the main question that we are studying here.

The data contained in Fig. 1 are more extensive than any other which we have found and comprise tests of finished steel in the shape of bars, angles, etc. The results of these tests corroborate the tests of blooms in Table IV, in that the tensile

TABLE VI.—IRREGULARITY IN TESTS OF UNFORGED STEEL FROM COMPRESSED AND UNCOMPRESSED INGOTS.
AVERAGE DEVIATIONS FROM THE AVERAGE.

REFERENCES.	Tensile Strength, lbs. per sq. in.		Elastic Limit, lbs. per sq. in.		Elongation, per cent.		Reduction of Area, per cent.	
	Com- pressed.	Uncom- pressed.	Com- pressed.	Uncom- pressed.	Com- press'd.	Uncom- press'd.	Com- press'd.	Uncom- press'd.
Greenwood, No. 2 . . . Longitudinal.	2,543	1,360	1,471	540	3.25	3.34	0.53	2.02
Greenwood, No. 2 . . . Transverse.	3,271	5,100	1,864	600	1.39	3.26	1.53	1.98
Beutter, No. 3. Natural.	2,290	7,824	2,827	944	2.2	3.2	2.5	4.0
Beutter, No. 3' Heated to 1000° C.	2,656	10,700	922	5,100	2.5	2.4	3.1	4.8
Beutter, No. 3	1,456	500*	1,039	800*	2.0	0.1*	4.7	1.4*
Harmet, No. 4	5,096	7,756	2,111	4,900	1.7	1.8	10.1	2.8
Capron, No. 5	4,150	10,850	.....	.....	6.0	7.5	.....	.....
Totals	20,006	43,590	9,195	12,084	17.04	21.70	17.76	15.60

strength in each case is higher in the compressed steel. The general average of all the tests included shows 12 per cent. greater strength together with 8 per cent. greater elongation in the compressed than in the uncompressed steel.

It has been stated that liquid compressed steel is not as homogeneous in physical quality as uncompressed steel and that there is a greater variation between the maximum and minimum physical tests, but an examination of all the data at hand shows that this claim is not supported by facts. In Table VI we have shown the

* As there were only two tests of this uncompressed ingot, located next to each other, there was but little opportunity for variation; therefore this line is omitted from the totals.

average deviation from the average results of each of the series of tests of ingots published. The collected data (omitting one series where there were only two tests of uncompressed steel shown, and therefore only a very limited opportunity for variation) show that the compressed steel is more uniform in tensile strength, elastic limit, and elongation, but less so in reduction of area. A closer study of the results shows that this apparent exception in the case of reduction of area is due to two abnormal tests in Set No. 6, Table I, and therefore correspondingly little weight is to be attached to it.

TABLE VII.—IRREGULARITY IN TESTS OF FORGED STEEL FROM COMPRESSED AND UNCOMPRESSED INGOTS.

AVERAGE DEVIATIONS FROM THE AVERAGE.

REFERENCES.	Tensile Strength, lbs. per sq. in.		Elastic Limit, lbs. per sq. in.		Elongation, per cent.		Reduction of Area, per cent.	
	Com- pressed.	Uncom- pressed.	Com- pressed.	Uncom- pressed.	Com- press'd.	Uncom- press'd.	Com- press'd.	Uncom- press'd.
Harmet, No. 4.	5,125	9,539	(9,923)	.....	1.71	3.66	20.0	22.6
Series 1.								
Harmet, No. 4.	2,107	7,008	2,459	10,962	1.46	3.31	8.7	24.2
Series 2.								
Capron, No. 5.	538	438	.....	.....	0.75	0.75	.....	.....
Osann, No. 7.	5,933	2,322	.....	.....	2.86	3.56	.....	.....
Series 1.								
Osann, No. 7.	5,279	4,433	.....	.....	5.05	4.47	.....	.....
Series 2.								
Osann, No. 7.	323	1,700	.....	.....	2.60	2.13	.....	.....
Series 3.								
Totals.	19,305	25,440	2,459	10,962	14.43	17.88	28.7	46.8

The homogeneity of forged steel from compressed ingots is better in the tests before us than that of forged steel from uncompressed ingots. It will be seen from Table VII that the sum of the average deviations from the average is much less in the case of tensile strength, elastic limit, and reduction of area, and nearly 20 per cent. less in the case of elongation.

CONCLUSION.

In conclusion, compression during solidification lessens the liability of steel to contain the remnants of pipes, blowholes, segregation, and external cracks, and partially prevents the development of a weak structure during crystallization. So far as

is shown by the tests we have been able to find, it also slightly increases the strength of finished steel, and increases its toughness under impact, besides making the different parts of ingots more uniform in quality both before and after rolling.

Several compression processes have been devised, but it is not our object to describe them here.* There are at least 18 plants in England and Europe equipped with a total of 30 to 40 presses,† and at least 3 or 4 plants, so far as we are informed, with about an equal number of presses, in America.

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*See Ref. 1, pp. 155–161; Ref. 9, pp. 250–265; Refs. 10, 11, and 12.

†See Refs. 12 and 13.

DISCUSSION.

Mr. Howe. **MR. H. M. HOWE.**—I should like to say a word about the conditions which exist in the compression of these ingots, particularly in the Harmet process, which differs from preceding ones. In the Harmet process you have a tapered ingot which is forced along through a tapered hole by pressure applied at the bottom, and in that way the skin of the ingot is at all times under compression. This is an advantage over the Whitworth system, in which the pressure is applied at the top of a cylindrical ingot, and tends to make it open up like the staves of a barrel, forcing the rich segregated matter from the interior into the crevices thus formed at the outside. I think we should understand how the thing is done before we can discuss it very profitably.

The first point that I want to consider is the effect of this compression upon segregation. We can readily understand that the compression of the Harmet process should, during the latter part of the solidification, squeeze the still molten segregate up into the top of the ingot so that it would fill the place where the pipe would have been if there had been no compression. That is of importance as regards the segregation of phosphorus and sulphur, because it moves the region enriched in these two harmful elements up into the top of the ingot where it can be cut off and thrown away. But this action in and by itself would be of little value as regards the segregation of carbon, because the harm which segregation does is making the carbon content irregular in the different parts of the ingot. In spite of this Harmet compression the lower part of the axis should, as far as this movement of the segregate is concerned, still remain impoverished in carbon, and this impoverishment would in general be very objectionable.

If further investigation should confirm the belief that the Harmet compression does lessen the segregation of carbon, and so does tend to make the carbon more uniform throughout the ingot, this itself would be a very important matter both technically and scientifically. It would be important scientifically, because it would show that one of the supposed causes of segregation was

really an important one, as I shall now try to explain. The cause to which I refer is the escape of gas from blowholes, which, as there is reason to believe, is one important cause of segregation. This gas escapes from the shores of the frozen part of the ingot into the molten mother metal within, and so causes an upward current in the molten mass along the walls of the frozen part. This upward current has two effects. First, it tends to wash off the incipient pine-tree crystals and so to divert the course of solidification from the land-locking to the onion type, and prevent the impurities from being locked up by the little crystals which grow out from the frozen walls into the molten metal. The rising current has an additional effect of sweeping upwards along the walls the littoral layer enriched in impurities by the act of freezing itself. In this way the rising current tends to carry the impurities to the top of the ingot. Now if the escape of gas from the blowholes can be prevented, then both these agencies by which segregation is increased are in like proportion impeded, and the segregation is itself lessened.

The only way in which, so far as we see, this Harmet compression can lessen segregation is by preventing the escape of gas from blowholes. Hence if we should find that the Harmet compression does lessen segregation to an important degree, we should naturally infer that it had done so by means of lessening the escape of gas from blowholes, and from this we should in turn infer that the escape of gas from blowholes was an important cause of segregation.

In regard to the quality of the metal being affected by the closing up of the blowholes and lessening the segregation, that is, of course, of great use; but does this compression improve the quality of the metal over and above that? To take a compressed ingot and compare it with an uncompressed ingot gives us no information at all on this head, because compression itself is a forging operation. Uncompressed metal is a casting, and everybody knows that a forging is better metal than a casting, other things being equal; so that, to compare a compressed with an uncompressed ingot does not tell us anything, because we know that a forging is better than an uncompressed casting.

Now does this compression bring about some change or other which is going to persist, so that when you take a compressed

Mr. Howe. ingot and forge it out into a rail, or axle, or other product, it is going to be better, because of something that has occurred during the compression, than a rail or axle from an uncompressed ingot? Compression is in one sense forging; it differs from our common forging, I take it, in that it takes place at a higher temperature than you can get in common forging. If we conceive the moment when nearly the whole of the metal is molten and only a very small part of it is solid, you can have compression going on then, and in that way get a forging of the metal when it is nearer to the melting point than you can in rolling or hammering. Now does that do any good? Is there any merit in doing this work of compression at a higher temperature than you can get in the ordinary process of forging?

I do not know that any of us are in a position to answer that question. It is a fair question. I can but say that the only evidence I have been able to find is in Mr. Howard's very careful description of his work on the Harmet ingot which he examined, and that so far as the evidence goes, there is nothing gained in this respect by carrying on this distortion, this forging at these extremely high temperatures; and the way in which it says it is this: If you examine Mr. Howard's results you will find that all the best of the test pieces came from either the outside of the ingot where the conditions of compression are most closely like those that you get with the hammer or rolls. But in the interior where the compression takes place at a higher temperature, when the metal was very hot, perhaps just beginning to solidify, he found pretty poor material. There was a very marked difference. This material from the outside was very much better than that from the inside, which as far as it goes means that compression at the common temperature that we use in forging or rolling is better than compression at higher temperature in its effect on the physical properties, tensile strength, elongation, etc., of the resultant steel. That is, of course, only a straw which does not absolutely prove anything.

When we come to consider the properties of this steel made by steel forged out of a compressed ingot and similar steel forged out of an uncompressed ingot, we have a number of tables which Mr. Stoughton has given. I think these must be studied with a great deal of care. I went far enough in studying

them to feel the need of very great caution. For instance, Mr. **Mr. Howe.** Harmet's results are at first very attractive; but after you come to consider them a little you notice that all the tests which he examines are right from the axis of the ingot. Well, I think we will be prepared to admit that compression, if it did any good anywhere, would benefit the metal right in the axis of the ingot, because in an uncompressed ingot, even if you did not see any pipe leading down to the bottom, you will find that the metal is pretty light and spongy in the very axis of the ingot, and it would be better for a little compression. This spongy portion may not have cavities which are readily visible to the eye, but they are there. You hear people speaking about visible and invisible pipe, meaning that the axis of the ingot is of material which is not particularly solid. So I do not doubt that this liquid compression ought to have a very important effect on this axial metal. Mr. Harmet's tests referring exclusively to the material from the very axis of the ingot, it seems to me are misleading in that respect, because they do not tell us about the bulk of the rest of the metal. That metal in the very axis of the ingot is usually much less important than the rest. If, for instance, the ingot is rolled out into an I beam, or a rail, then this metal which was in the axis of the ingot lies in or near the neutral axis of the finished piece. The quality of metal in the neutral axis is of course far less important than that of the rest of the metal.

Then again, when you come to compare Mr. Harmet's forged pieces, you will find something which sets you thinking; you will find that the forged pieces from the compressed ingot have an enormously high elastic ratio. How is that? Is it conceivable that this distortion in his liquid compression at this very high temperature can have this particular effect of raising the elastic ratio of the cold and finished metal? Is it possible rather that Mr. Harmet has unintentionally not treated the two pieces alike, the compressed and the uncompressed? Has he treated them in different ways in his subsequent forging? Did he forge his pieces from the compressed ingot down to a lower temperature? Did he have a lower finishing temperature in the case of the compressed than in the case of the uncompressed ingot? Is this very high elastic ratio in the forgings from compressed ingots due to a lower finishing temperature? Is it due to a wholly unfair method

Mr. Howe. of comparison, or not? These are questions which require very careful study of the data submitted.

You will find the same thing reflected in Mr. Harmet's impact tests. You will find evidences of cold working of these specimens from compressed ingots which you do not find in the specimens from uncompressed ingots; and so on with a good many others. Professor Osann made three sets of tests; in two of the three I do not see that there is any advantage at all that the compressed ingot has over the uncompressed. It looks to me as if there were no particular advantages. In the third there is an advantage. I think it would be well to take this third set, study it out very carefully, and see if there is not some explanation which does not indicate that the superiority is due to compression.

I think we are all greatly indebted to Mr. Stoughton and others who have taken a hand in bringing these important data before us.

Mr. Howard. **MR. J. E. HOWARD.**—Some information has been acquired in regard to cubic compression at the Watertown Arsenal on the effect, or rather non-effect, of compression when cold. Steel has been put into a hydrostatic press and subjected to a pressure, on all sides, of 117,000 lbs. per sq. in., its physical properties being in no way affected by reason of that compression. Similarly, a limestone cube, having a crushing strength of about 11,000 lbs. per sq. in., was put in the press, enclosed in a thin brass envelope to keep water from entering, and there subjected to a pressure of 30,000 lbs. per sq. in. Its strength, when tested subsequently, was found to be normal; that is, the effect of cubic compression nearly three times its usual crushing strength had no influence upon it. Then again a small cylinder of Portland cement was subjected to a cubic compression of 100,000 lbs. per sq. in., and apparently no injury done. So it would seem that compression as such might not and should not be expected when done cold to change the physical properties of ordinary material. Whether it does when hot I cannot say, but I see no reason for expecting that it would change the physical properties of the steel except in so far as might follow from the closing of blowholes.

Mr. Snow. **MR. J. P. SNOW.**—I should like a little information on the matter of solidifying ingots, not exactly in the line of compressing them which this paper deals with. I wish to learn whether there is any benefit in agitating a mold while the metal is in a fluid state;

as might occur if a mold is poured on a car and that car is run at a fairly good rate of speed over a rough track, or over wheels that have flat spots on them, etc. We all know that agitation is an effective way to separate materials by gravity. If we have a mixture of materials of different specific gravities, a little agitation will bring the light ones to the top. Now there is a difference in the specific gravity of the ingredients in an ingot mold, especially between the gas bubbles and the metal; and whether or not agitation would assist in inducing those bubbles and their impurities to go to the top of the ingot I do not know. Is there anyone here who can tell us? Mr. Snow.

MR. HOWE.—Professor Tschernoff proposed to churn those off. He rotated an ingot at a speed increasing continuously to a maximum, and then decreasing to a minimum. I believe that it was done also at one time at the Northwestern Steel Works near Liverpool in making the centers of locomotive driving wheels. In steel castings I do not think they got such benefit as to warrant keeping on. May I say one more word that I forgot to say about the Harmet ingot? I think it is instructive that the tests which Mr. Howard got were so very bad. You may say that this was an unfortunate failure, and that a new process should not be judged by a single failure due to its immaturity. But certainly the properties of this steel were not materially better than those of an unforged and unannealed steel casting. Mr. Howe.

MR. BRADLEY STOUGHTON.—I should like to ask Mr. Howard if there was anything in the appearance of this nickel-steel Harmet ingot to indicate whether or not the poor results obtained in tension were due to blowholes? In other words, might they not have been caused by faulty manufacture of the steel itself rather than by failure of the compression process? I take it that the lines of unsoundness might have been produced by the flattening out of blowholes during the application of compression, and this inference would be confirmed somewhat by the circumstance that the results of tests on pieces cut from the center of the ingot were worse than those on pieces cut from portions where blowholes would not be expected to form so readily. Mr. Stoughton.

MR. HOWARD.—The low values shown by the tensile tests were found in specimens which cut the structural defects of the ingot at unfavorable angles. Mr. Howard.

NOTES ON THE ANNEALING OF MEDIUM CARBON STEEL.

BY WILLIAM CAMPBELL.

In a former paper the question whether ingotism could be completely cured by prolonged exposure to the temperature at which overheating is cured, was dealt with.* Pieces of a steel casting containing C., 0.43, Si., 0.4, Mn., 0.78, P., 0.05, S., 0.05 per cent., were heated to various temperatures between 805° and 1195° C., and their microstructure examined. It was found that the coarse network of ferrite was not completely removed at 1180° C., but a piece heated to 1195° C. showed no trace of it.

The critical points of the steel were $Ac_1 = 760^\circ\text{C.}$, $Ar_1 = 705^\circ\text{C.}$, and $Ar_{2-3} = 762^\circ\text{C.}$ Heating to 840° C., well above Ac_{2-3} , for 32 hours, failed to remove the ferrite network.

The changes in structure can be observed in the following photomicrographs. The structure of the original casting is shown in Fig. 1. The white constituent is ferrite, the black is pearlite, the whole showing the very coarse structure of untreated castings. Heating to 805° C. refined the ground mass but left the long coarse lines of ferrite unchanged, except that the parallel spines of the original were dissolved, as seen in Fig. 2. Heating to 840° C. refined the specimen with the exception of very fine veins of ferrite, which were found to persist to 1180° C. Fig. 3 shows the specimen heated to 860° C. The structure is extremely fine, but the faint network of ferrite can be seen forming a polygonal grain. This is typical of the specimens heated to 1000°, 1006°, 1120°, 1170°, and 1180° C.

Fig. 4 shows the specimen heated to 1195° C. The ferrite network has disappeared and a new, coarser grain is making its appearance. [The specimen heated to 1180° C. showed no signs of this new coarse grain, which is contrary to the generally accepted idea that the higher the temperature of heating above the critical point, the coarser the grain progressively. In this case it would

* Howe, Campbell and Koken. Proceedings, Vol. VIII, p. 185.



FIG. 1.—Original Casting. ($\times 38$.)

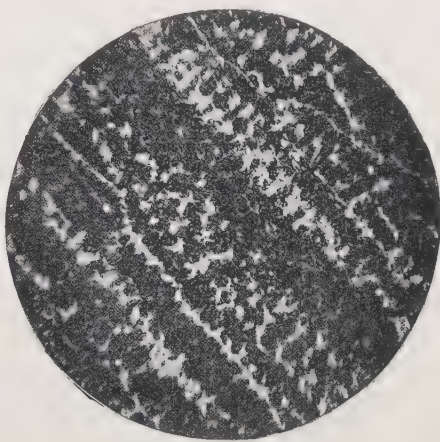


FIG. 2.—Heated to 805°C . ($\times 38$.)

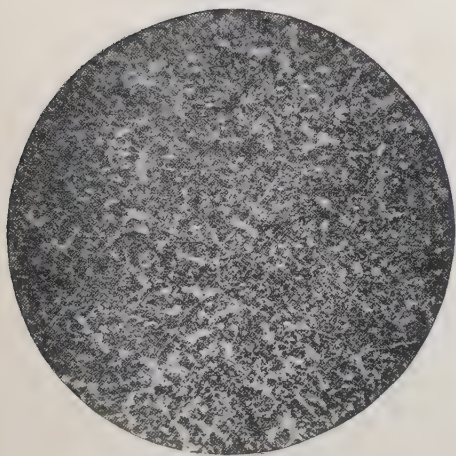


FIG. 3.—Heated to 860°C . Almost refined. ($\times 42$.)

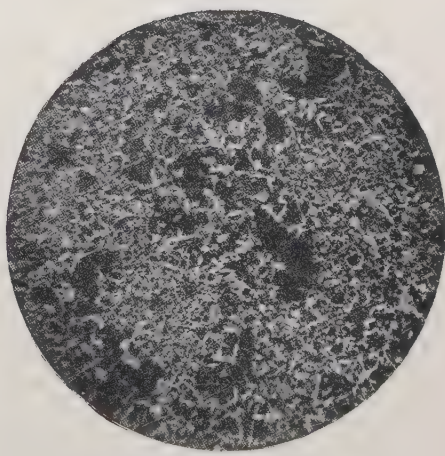


FIG. 4.—Heated to 1195°C . Beginning of coarsening of grain. ($\times 42$.)

C. = 0.4. Mn. = 0.78.

seem that the grain suddenly became coarser at about 1190°C . (Fig. 4), showing both the coarse and the fine-grained structure. In other words, overheating does not take place till 1190°C . is reached. [A critical point has been indicated in this region by several workers.] On the other hand, a specimen after overheating at 1375°C . was found to be refined by heating to 840°C .

The present work was done to determine the reason for the persistence of the thin films of ferrite (Fig. 3), which were thought to be due to precipitation of ferrite on thin flakes of manganese sulphide or slag which formed in the original casting.

Two pieces of steel castings were obtained. The first contained C., 0.35, Mn., 0.66, S., 0.06, and P., 0.07 per cent.; the second contained C., 0.50 per cent., the other elements being practically the same. The main point of difference, however, lay in the fact that in the first specimen what manganese sulphide or slag there was present, occurred in the form of small globules evenly distributed, whilst in the second these impurities were found to occur in strings or veins—that is to say, they were markedly segregated.

The specimens were heated in an electric furnace to the temperatures indicated in Table I, which lie in the neighborhood

TABLE I.

Temperature, Degrees Centigrade.	No. 1. C. = 0.35 per cent.	No. 2. C. = 0.50 per cent.
735	Not refined (Fig. 6)	Not refined (Fig. 10).
805	Not refined	Not quite refined (Fig. 11).
830	Not quite refined (Fig. 7) . .	Not quite refined.
855	Refined (Fig. 8)	Not quite refined (Fig. 12).

of the critical points, held there for 15 minutes and then slowly cooled in the furnace.* The time of heating to maximum temperature was an hour and a half or more. Sections were cut in the usual way and examined. The critical points were as follows:

C. = 0.35 per cent.			
Ac ₁	Ar ₁	Ac ₂₋₃	Ar ₂₋₃
740°	665°	810° (about)	735°

* This work was done by Mr. Ch'en Wei Fan, in the Metallographic Laboratory, Columbia University, New York.



FIG. 5.—Original Casting. ($\times 36$.)

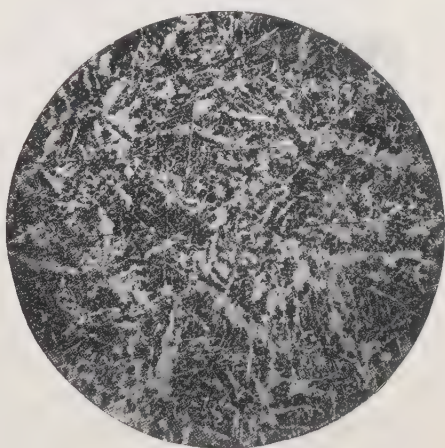


FIG. 6.—Heated to 735°C . ($\times 38$.)

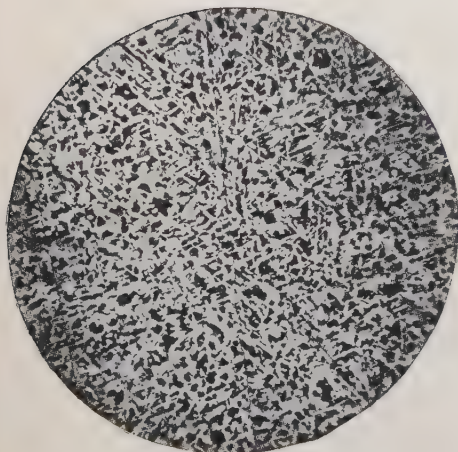


FIG. 7.—Heated to 830°C .
Almost refined. ($\times 36$.)

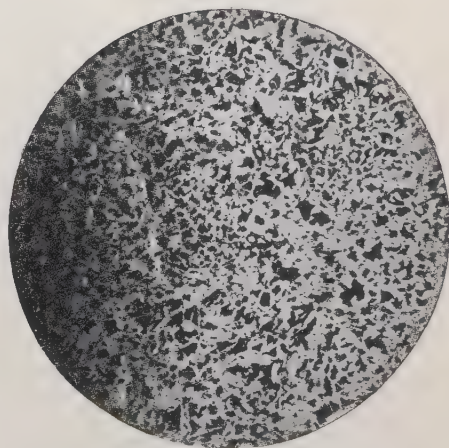


FIG. 8.—Heated to 855°C .
Refined. ($\times 36$.)

C. = 0.35. Mn. = 0.66.

Steel No. 1. $C.=0.35$, $Mn.=0.66$.—The structure of the original casting is shown in Fig. 5. This structure is characteristic and consists of white ferrite in a background of dark-etching pearlite. Only part of one grain is seen, and the triangular arrangement of the ferrite is due to the structure of the original solid solution, austenite, out of which it separated on reaching Ar_{2-3} .

Heating to $735^{\circ}C.$ for 15 minutes has refined the pearlite, but has left the large veins and envelopes of ferrite unrefined, shown in Fig. 6. The $805^{\circ}C.$ heat carried the change further and took a great deal of the ferrite into solution; while the same thing is shown in Fig. 7, heated to $830^{\circ}C.$, where only a trace of the original structure remains and is shown in the indistinct triangular arrangement of some of the ferrite. The last heat, to $855^{\circ}C.$, is seen in Fig. 8, a fine-grained mixture of ferrite and pearlite, and refining is complete.

Steel No. 2. $C.=0.50$, $Mn.=0.68$.—The material as received had been heated commercially in an attempt at refining. Its structure is shown in Fig. 9. The ground mass is a fine-grained mixture of ferrite and pearlite. Throughout the metal there is a coarse system of veins of ferrite with cores of manganese sulphide or slag. Their nature is clearly seen in Fig. 10, in which we have the remains of a dendrite or pine-tree crystal of austenite, the manganese sulphide or slag forming the background which solidified last of all in the interstitial spaces. When the casting had cooled down to Ar_{2-3} , the excess ferrite started to separate out on these nuclei of manganese sulphide, etc., and continued to do so down to Ar_1 , at which temperature the remaining austenite changed over into pearlite.

Heating to $735^{\circ}C.$ did not cause any appreciable change, (Fig. 10). The $805^{\circ}C.$ heat is shown in Fig. 11. The veins of ferrite are still present though less distinct. The $830^{\circ}C.$ heat was similar, while heating to $855^{\circ}C.$ failed to completely refine the specimen. This is shown in Fig. 12, where indistinct veins of ferrite are still seen surrounding particles of manganese sulphide or slag.

Thus in the case of the first steel, showing no network of manganese sulphide or slag globules, refining was complete on heating a little above Ac_{2-3} , say $850^{\circ}C.$ In the second steel,

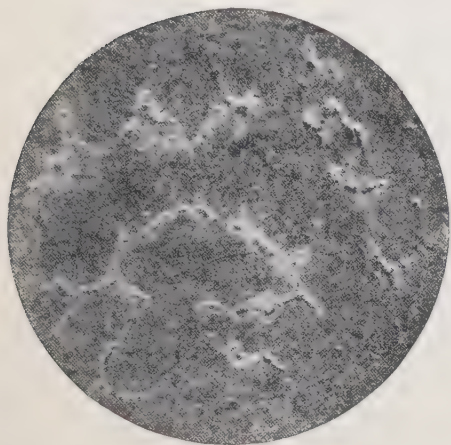


FIG. 9.—Casting as received. Unrefined.
($\times 36$.)



FIG. 10.—Heated to 735°C .
Pine-tree crystallization. ($\times 21$.)

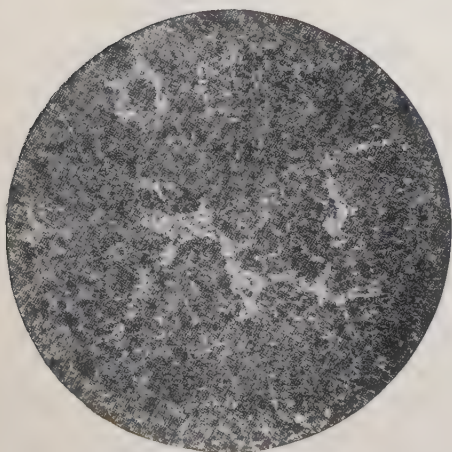


FIG. 11.—Reheated to 805°C .
Not quite refined. ($\times 38$.)

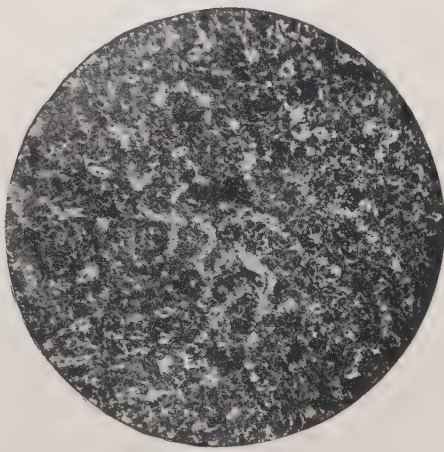


FIG. 12.—Reheated to 855°C . Trace of
white vein structure remains. ($\times 45$.)

C. = 0.50. Mn. = 0.68.

possessing a network of manganese sulphide or slag globules as seen in Figs. 9 and 10, refining is not brought about completely by heating a little above Ac_{2-3} , due to the fact that ferrite persists around these nuclei.

To find the effect of varying the time of heating, another set of specimens were heated in the same way, but kept at the maximum temperature for one hour or more, then slowly cooled. Three temperatures were chosen, one at the critical point, Ac_1 , one between this and Ac_{2-3} , and one just above Ac_{2-3} .

TABLE II.

Temperature, Degrees Centigrade.	No. 1. C. = 0.35 per cent.	No. 2. C. = 0.50 per cent.
760	Not refined	Not quite refined (Fig. 11).
795	Not quite refined (Fig. 7) . .	Not quite refined.
830	Refined (Fig. 8)	Not refined.

In the case of the first steel, C.=0.35 per cent., heating to 795° C. for one hour was not quite sufficient to entirely obliterate the triangular structure of the ferrite, and the resulting structure was identical with that of Fig. 7. Heating to 830° C., however, completed the refining and the structure was found to be the same as that shown in Fig. 8.

In the second steel, C.=0.50 per cent., heating to 760° C. for one hour gave a structure similar to that in Fig. 11, while the 830° C. heat was no better.

Thus by increasing the time of holding the specimen at the maximum temperature from 15 minutes to an hour or more, the refining was found to occur nearer to Ac_{2-3} , or some 25° C. lower in the one case; but when manganese sulphide or slag globules were present, as in the second steel, no benefit was obtained by prolonging the heating.

CONCLUSIONS.

Medium carbon steel castings can be completely refined as regards grain size by heating to temperatures a little above Ac_{2-3} , as in the case of rolled or overheated material, except when there is

a network of manganese sulphide or slag globules present. This latter prevents *complete* refining by acting as nuclei on which the ferrite precipitates. The best results, however, are obtained in both cases by heating to temperatures a little above Ac_{2-3} .

Heating this cast material up to 1150° C. for several minutes does not cause a marked coarsening of the grain as was expected.

TESTS OF STANDARD I BEAMS AND BETHLEHEM SPECIAL I BEAMS AND GIRDER BEAMS.

By EDGAR MARBURG.

The new Bethlehem special I beams and girder beams, rolled on the Grey universal beam mill, at the works of the Bethlehem Steel Company, South Bethlehem, Pa., differ in certain important particulars from the so-called "standard" beams. In the Grey mill the flanges and web of the beam are formed by the simultaneous operation of independent horizontal and vertical rolls, thus admitting of the effective rolling of the metal in the flanges as well as the web. This renders it possible to produce wider flanges than by beam mills of the ordinary type in which the linear speed of rolling at different points of the beam varies inversely with the distance from the center of the roll, resulting in a dragging action upon the flange metal, which becomes emphasized with increasing flange width. It is claimed that sections produced by the Grey process are also subjected to uniform reduction in rolling at all parts of the shape, resulting in greater uniformity in the physical properties of the material throughout the section, and in the avoidance of internal stresses, and that, in consequence, under nominally the same working stresses, they possess a larger safety margin than beams made by the usual method. It is further claimed that the webs of the standard beams are unnecessarily thick for economy, but that it is not practicable to reduce their thickness in the ordinary mill. Compared with the lightest standard beams of like depth, the lightest Bethlehem special I beams are designed so as to possess the same section moduli at weights uniformly 10 per cent. less. This is effected by a material decrease of web section and a slight increase of flange section, the comparison for the lightest 24 and 15-in. beams being approximately as follows:

	24-in. Beams.		15-in. Beams.	
	Std. 80 lbs. Sq. ins.	Beth. 72 lbs. Sq. ins.	Std. 42 lbs. Sq. ins.	Beth. 38 lbs. Sq. ins.
Web section.....	10.9	8.1	5.5	3.8
Flange section.....	12.4	13.1	7.0	7.4
Total.....	23.3	21.2	12.5	11.2

By adding one-sixth of the metal deducted from the web to each flange, the section modulus would remain unchanged, provided the depth between centers of gravity of the flanges is unaffected. Since the flanges of the Bethlehem beams are wider and thinner, however, than those of the standard beams, the flange metal in the former is more favorably disposed; hence the increase of each flange area, for equal section modulus, will be slightly less than one-sixth the area taken from the web as seen from an analysis of the values in the above table. The slope of the flanges of the Bethlehem beams is one-fourth less than that of the standard beams, or 1 on 8 instead of 1 on 6.

The Bethlehem girder beams are so designed that the lightest section of a given depth below 24 ins., possesses just twice the section modulus of the lightest standard beam of corresponding depth, whereas the weight of the former averages about 12.5 per cent. less than the double weight of the latter. The web thicknesses are practically identical, the difference lying chiefly in the greatly increased width and slightly increased thickness of the flanges. For the greatest depth of section of standard beams, 24 ins., the section modulus of the lightest girder beam is somewhat less than twice that of the lightest standard beam, as seen in Table I.

The lightest section of each of the three types, for depths of 15, 24 and 30 ins., is shown in Figs. 1, 2, and 3. The largest Bethlehem girder beam is 30 ins. deep and weighs 200 lbs. per foot; the largest standard beam is 24 ins. deep and weighs 100 lbs. per foot. The section moduli are 610 and 198 respectively, the former being more than three times as great as the latter, although the weight is only twice as great, this advantage being due partly to the difference in depth, and partly to the more favorable distribution of the material between the web and flanges.

The claims advanced in favor of the Bethlehem as compared with the standard beams, briefly summarized, are:

1. That the material in the flanges receives more work in rolling and is, therefore, of better quality.
2. That the material throughout the section is more nearly uniform in quality.
3. That the beams are comparatively free from internal stresses.

If these claims are valid, it obviously follows that the Bethlehem beams are stronger for like section moduli, provided the relatively thin webs do not induce premature failure by buckling.

In view of the importance of the subject to the engineering profession, and the desirability of determining by actual tests the validity of the above claims, the writer proposed to the Bethlehem Steel Company, to conduct at the expense of that Company, in the laboratories of the Department of Civil Engineering, University of Pennsylvania, an extended series of comparative tests between Bethlehem and standard beams, reserving to himself

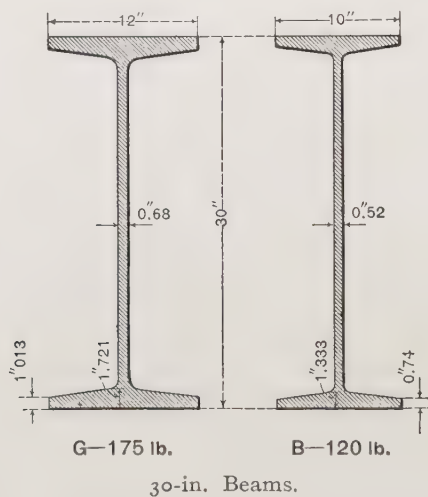


FIG. 1.

only the right of publication. This proposal was accepted, and a program of tests was accordingly drawn up by the author in conference with Mr. George H. Blakeley, Structural Engineer of the Bethlehem Steel Company. This program was regarded at the time as a preliminary one to be further elaborated, or modified, in the light of experience. In that expectation the writer was disappointed, since even the material for the completion of the program originally agreed upon had not been wholly supplied when the tests came to an unexpected termination last December. If the results of these tests, which are all embodied in this paper,

point conclusively to one thing, it is the importance of continuing these investigations on greatly extended lines.

Material Schedule.—From the material schedule in Table I it is seen that the preliminary program referred to embraces 33

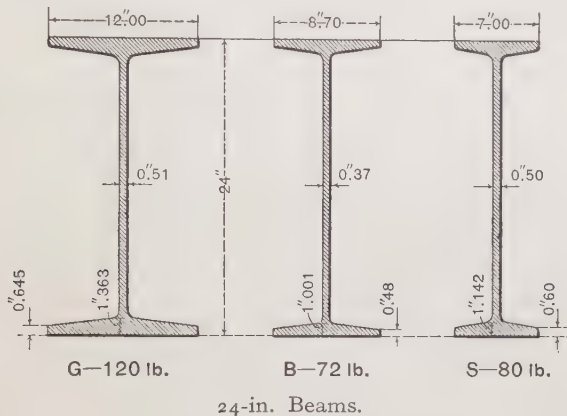


FIG. 2

beams, ranging from 15-in. sections weighing 38 lbs. per foot, to 30-in. sections weighing 175 lbs. per foot. The total weight of material involved is about 25 tons. The beams are in every

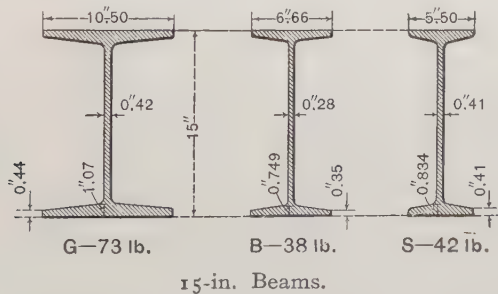


FIG. 3.

case the lightest sections of their respective types and depths. The table exhibits also a comparison between the actual and nominal weights and section moduli of the beams. It was thought best to use the nominal rather than the actual values in connection

with all computations, since it is the former that are necessarily used in practice, and since all specifications permit variations of weights within certain limits, seldom exceeding, however, 2.5 per cent. The only marked departures from that limit occur in the case of the three 24-in. Bethlehem special I beams, which run from 4.8 to 6.4 per cent. above their nominal weight, with section moduli too high by 2.4 to 3.1 per cent.

The Bethlehem beams were selected at random from given

TABLE I.—MATERIAL SCHEDULE.

Lab. No.	Type.	Depth, in ins.	Weight in lbs. per ft.			Section Modulus.			Chemical Analysis.			
			Nominal.	Actual.	Diff. per ct.	Nominal.	Actual.	Diff. per ct.	Carb.	Mang.	Phos.	Sul.
B1	Beth. I	15	38	38.7	+1.8	59.0	59.5	+0.8	0.20	0.68	0.022	0.033
B2	"	"	"	38.4	+1.0	"	59.3	+0.5	"	"	"	"
B3	"	"	"	37.4	-1.6	"	58.6	-0.7	"	"	"	"
S4	Std. I	42	41.4	41.4	-1.4	58.9	58.5	-0.7	0.22	0.41	0.012	0.040
S5	"	"	"	41.3	-1.7	"	58.4	-0.8	"	"	"	"
S6	"	"	"	41.4	-1.4	"	58.5	-0.7	"	"	"	"
G7	Girder	73	73.7	73.7	+1.0	118.2	118.7	+0.4	0.26	0.59	0.016	0.046
G8	"	"	"	74.9	+2.6	"	119.6	+1.2	"	"	"	"
G9	"	"	"	75.3	+3.1	"	119.9	+1.4	"	"	"	"
B10	Beth. I	38	36.8	36.8	-3.2	59.0	58.1	-1.5	0.20	0.68	0.022	0.033
B11	"	"	"	36.7	-3.4	"	58.0	-1.6	"	"	"	"
B12	"	"	"	36.8	-3.2	"	58.1	-1.5	"	"	"	"
S13	Std. I	42	41.4	41.4	-1.4	58.9	58.5	-0.7	0.22	0.41	0.012	0.040
S14	"	"	"	41.2	-1.9	"	58.3	-1.0	"	"	"	"
S15	"	"	"	41.2	-1.9	"	58.3	-1.0	"	"	"	"
G16	Girder	73	75.0	75.0	+2.7	118.2	119.7	+1.2	0.26	0.59	0.016	0.046
G17	"	"	"	74.9	+2.6	"	119.6	+1.2	"	"	"	"
G18	"	"	"	75.2	+3.0	"	119.8	+1.4	"	"	"	"
B19	Beth. I	24	72	75.5	+4.8	174.2	178.3	+2.4	0.22	0.63	0.022	0.048
B20	"	"	"	76.6	+6.4	"	179.6	+3.1	"	"	"	"
B21	"	"	"	76.3	+6.0	"	179.3	+2.9	"	"	"	"
S22	Std. I	80	80.3	80.3	+0.4	173.9	174.2	+0.2	0.20	0.50	0.034	0.034
S23	"	"	"	82.2	+2.7	"	176.5	+1.5	"	"	"	"
S24	"	"	"	80.6	+0.7	"	174.6	+0.4	"	"	"	"
G25	Girder	120	123.7	123.7	+3.1	302.6	307.0	+1.4	0.19	0.85	0.016	0.047
G26	"	"	"	121.0	+0.8	"	303.8	+0.4	"	"	"	"
G27	"	"	"	122.3	+1.9	"	305.3	+0.9	"	"	"	"
B28	Beth. I	30	120	.....	.....	351.4	.....	.....	(?)	(?)	(?)	(?)
B29	"	"	"	.....	.....	.....	.....	.....	"	"	"	"
B30	"	"	"	.....	.....	.....	.....	.....	"	"	"	"
G31	Girder	175	176.9	176.9	+1.08	523.5	526.3	+0.5	0.18	0.86	0.022	0.031
G32	"	"	"	175.7	+0.4	"	524.5	+0.2	"	"	"	"
G33	"	"	"	174.3	-0.4	"	522.5	-0.2	"	"	"	"

heats, and stamped before shipment by the writer's representative with the exception of a few of the 15-in. beams which had been previously shipped. The standard beams were purchased by the Bethlehem Steel Company. The 15-in. beams were rolled at Pencoyd and the 24-in. beams at the works of the Jones and Laughlin Steel Company. The aim was to select the material from heats of about the same chemical composition. The carbon is seen to range from 0.18 to 0.26 and the manganese from 0.41

to 0.86 per cent. while the percentages of phosphorus and sulphur average about 0.02 and 0.04 respectively. Check analyses from sample drillings from the finished beams were not made, although in the opinion of the writer, it is desirable that this should have been done in connection with the specimens used for tensile tests.

TENSILE TESTS.

Three tensile tests were to be made on specimens cut from the beams from each heat of steel, one specimen to be taken from the web, another from the flange, and a third from the root. This program was, however, not fully carried out for reasons noted below. The finished specimens were all 1.5 ins. wide, with planed edges, and occupied approximately the positions in the sections



FIG. 4.—Showing Location of Tensile Specimens.

indicated in Fig. 4, which represents one flange and a part of the web of a 15-in., 73-lb. girder beam.

The elongations were measured on an 8-in. gauge-length with a Ewing extensometer, by which the deformation is doubled mechanically and its length determined by means of a microscope, the eye-piece of which is provided with a finely graduated scale admitting of direct readings to $1/5,000$ in., or to $1/50,000$ in. by estimation. The accuracy and reliability of this form of extensometer is due partly to the fact that its use entails no manipulation on the part of the observer during the test. This extensometer, on comparison with a Henning extensometer with Browne & Sharp micrometer screws, in a series of measurements within the elastic limit of a nickel-steel specimen, showed differences of from 0.1 to 0.2 per cent.

The results of these observations, reduced to unit elongations, are shown in Fig. 5, and in Figs. 6 and 7, Plate I.

The results of the tests on the two flange specimens of the 15-in. Bethlehem beams were rendered worthless through the eccentric attachment of the extensometer to the trapezoidal sections of these specimens. In the tests of the flange specimens recorded in Figs. 6 and 7, extraordinary care was used to place the contact points of the extensometer in a plane traversing the gravity axis of the trapezoidal sections, to eliminate the effect of bending. The accuracy with which this was done is attested by the straightness of the stress-deformation lines in these figures. Through an error at the mill, the tensile specimens for the 15-in. standard beams were

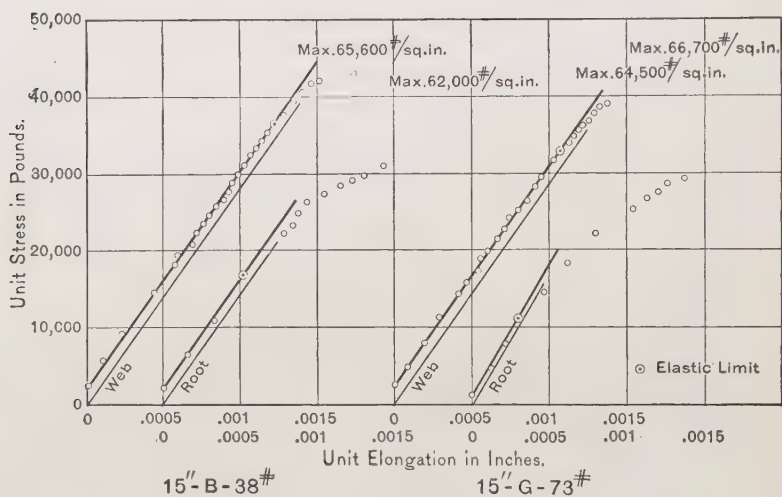


FIG. 5.—Tensile Tests, 15-in. Beams.

not prepared, and this error was not discovered until after the material had been scrapped.

In Table II are given the values of the elastic limit, ultimate strength, modulus of elasticity, and the percentages of elongation and reduction for the entire series of tensile tests. The most notable feature is the remarkably low values of the elastic limit in five of the seven specimens from the root, particularly in the case of the Bethlehem 15-in. girder beams for which the elastic limit at the root was only 11,000 lbs. In six of the seven sets of specimens the elastic limit was highest in the web, as was to be anticipated,

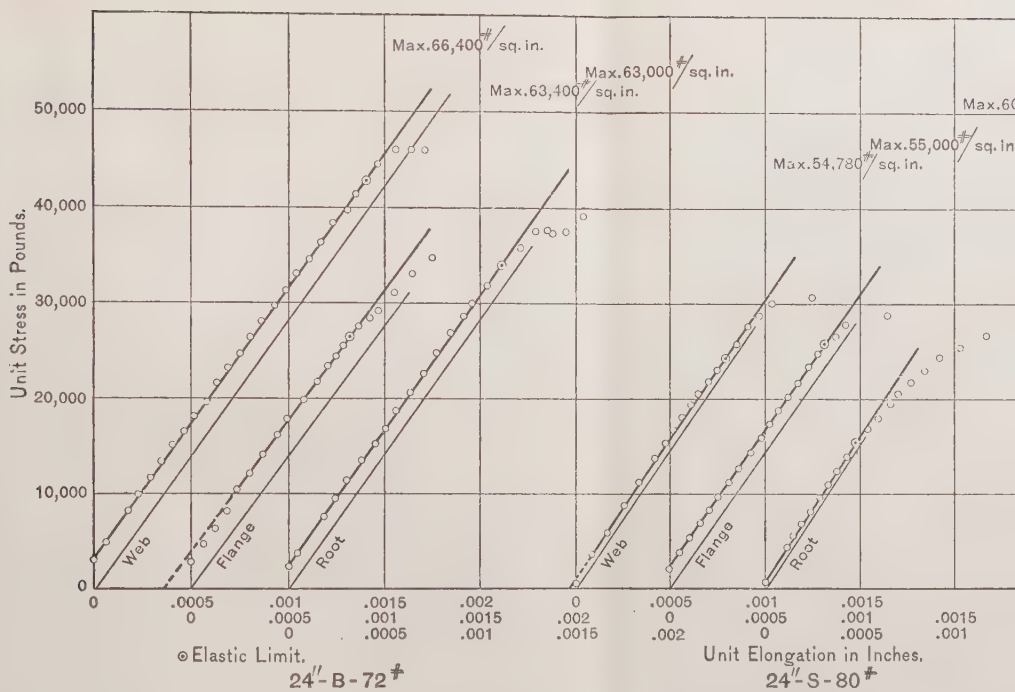


FIG. 6.—Tensile Tests, 24-in. Beams

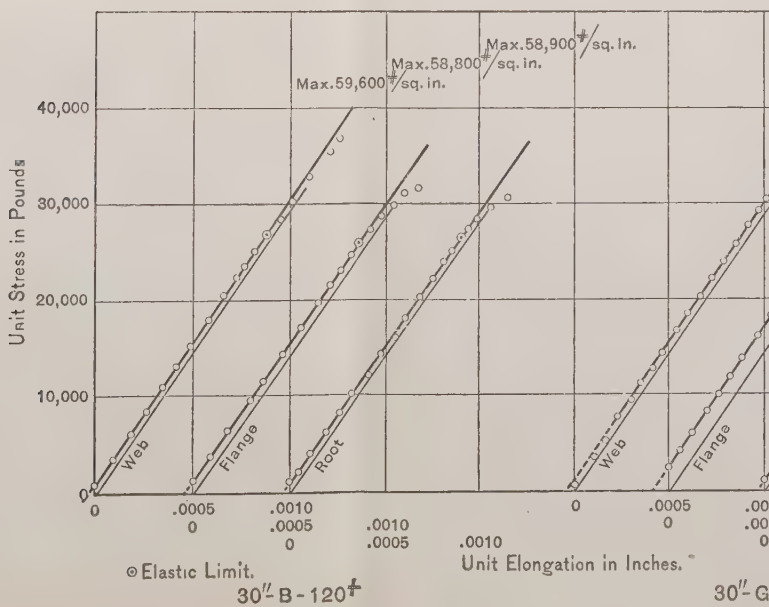


FIG. 7.—Tensile Tests, 30-in. Beams.

TABLE II.—TENSILE TESTS OF STEEL.

Type.	Size.	Test Piece.			Elastic Limit, lbs. per sq. in.	Yield Point, lbs. per sq. in.	Ultimate Strength, lbs. per sq. in.	Modulus of Elasticity in 1,000,000 lbs.	Elongation in 8 ins., per cent.	Reduction, per cent.
		Loca- tion.	Dimensions in ins.	Area in sq. ins.						
Beth. I	15 in.- 38 lb.	Web	1.50×0.29	0.435	36,800	42,500	65,000	28.2	27.5	48.5
"	" "	Flange			Test defective.					
"	" "	Root	1.49×0.25	0.373	16,300	34,400	62,000	28.0	17.5	36.6
"	24 in.- 72 lb.	Web	1.51×0.40	0.604	43,000	46,200	66,400	28.5	25.0	48.0
"	" "	Flange	1.51×1.50	1.060	26,400	36,100	63,400	28.0	29.0	57.5
"	" "	Root	1.48×0.36	0.533	33,800	39,400	63,000	28.4	...	53.8
"	30 in.-120 lb.	Web	1.50×0.55	0.825	26,700	37,000	59,600	29.1	32.0	53.5
"	" "	Flange	1.48×1.52	1.510	25,800	31,500	58,800	28.3	33.0	59.6
"	" "	Root	1.46×0.675	0.986	26,400	30,400	58,900	28.0	31.0	57.0
Std. I	15 in.- 42 lb.	Web			No test specimens furnished.					
"	" "	Flange								
"	" "	Root								
"	24 in.- 80 lb.	Web	1.45×0.52	0.754	24,500	30,500	54,800	28.9	...	30.9
"	" "	Flange	1.45×1.45	1.340	25,400	28,400	55,000	29.2	34.6	61.2
"	" "	Root	1.46×0.50	0.730	15,200	28,100	60,100	30.4	25.0	57.7
Beth.Gir.	15 in.- 73 lb.	Web	1.49×0.47	0.701	32,500	41,400	64,500	29.0	27.7	46.4
"	" "	Flange			Test defective.					
"	" "	Root	1.50×0.45	0.676	11,000	32,500	66,700	35.0	28.6	45.7
"	24 in.-120 lb.	Web	1.50×0.55	0.825	35,150	36,400	60,200	28.4	31.0	55.3
"	" "	Flange	1.49×1.49	1.380	31,900	33,300	61,500	28.7	34.8	65.1
"	" "	Root	1.51×0.59	0.891	20,200	29,300	56,700	29.6	...	61.2
"	30 in.-175 lb.	Web	1.51×0.72	1.090	34,000	34,900	59,500	28.7	32.0	62.5
"	" "	Flange	1.48×1.50	1.960	25,500	32,400	61,800	29.3	34.0	63.3
"	" "	Root	1.48×0.79	1.169	17,100	28,200	59,400	28.6	35.0	59.8

and in the seventh set the flange specimen gave a slightly higher value.

The abnormal character of the material in the specimens which displayed such low elastic limits is further apparent from the fact that the ratio of the yield-point to the elastic limit is, in these cases, much higher than in properly finished structural steel. This is clearly apparent in the stress-deformation curves, Figs. 5, 6, and 7, in which the highest point on each curve usually represents the yield-point. In a few instances the yield-point is not shown on the diagrams, but the values all appear in Table II. It is obvious, therefore, that the determination of the yield-point by the drop of the scale beam, gives, under such circumstances, not even approximate information as to the value of the true elastic limit.

It is to be observed that the recorded values of the elastic limit at the root of the 15-in. Bethlehem beams are probably somewhat too low by reason of the relatively large increments of loading between successive readings, as seen in Fig. 5. Had such remark-

ably low values been anticipated, the critical region would, of course, have been approached more cautiously. It is noteworthy that certain specimens which exhibit decidedly low elastic limits run particularly high in ultimate strength.

Unfortunately this inferior material exists at the root or thickest part of the flange where its effect on the strength of the beam is greatest. For fuller information as to the variability of the metal, it would be desirable to cut the entire section longitudinally into a series of thin strips of suitable length. By taking accurate extensometer measurements between a pair of contact points on each strip, before and after separation from the beam, its state of initial stress may be determined. While there seems to be some justification for the claim that Bethlehem beams possess greater freedom from initial stresses than standard beams, experimental proof is needed for its actual demonstration.

The elastic limits of the web and flange specimens are, as a rule, much more favorable than those of the root specimens. Nevertheless these values also are, on the whole, abnormally low. For the single set of tests of standard beams and for the Bethlehem 30-in. special beams the elastic limit is only about 45 per cent. of the ultimate strength; for the other Bethlehem beams this ratio ranges from 41 to 65 per cent.

The values of the ultimate strength are in fair accord with the chemical analyses of the various heats, with the exception of those for the standard beams which average about 10 per cent. too low.

The claim of superior uniformity in the physical properties of the material throughout the section, advanced in favor of the Bethlehem beams, is not substantiated by these tests. Of the six Bethlehem beams, in which the material was subjected to tensile tests, the uniformity with respect to the elastic limit was good in one case, fair in another, and bad in the remaining four. In the last four cases the elastic limit of the web exceeded that of the root by 195, 126, 99, and 74 per cent. respectively. The writer regrets that he was not afforded the desired opportunity of making numerous additional tests of this character. In the light of these results it would seem that the material in the vicinity of the root received insufficient work, or that it was finished at too high a temperature, or both, in the Bethlehem as well as the standard beams.

BENDING TESTS.

Span and Loading.—Of the 33 beams embraced in the material schedule, Table I, the first 9 were tested under central loading, and all the others under two equal loads, concentrated at the quarter-points. The span, center to center of end supports, was 15 ft. for all of the 15-in. beams, and 20 ft. for all of the 24 and 30-in. beams.

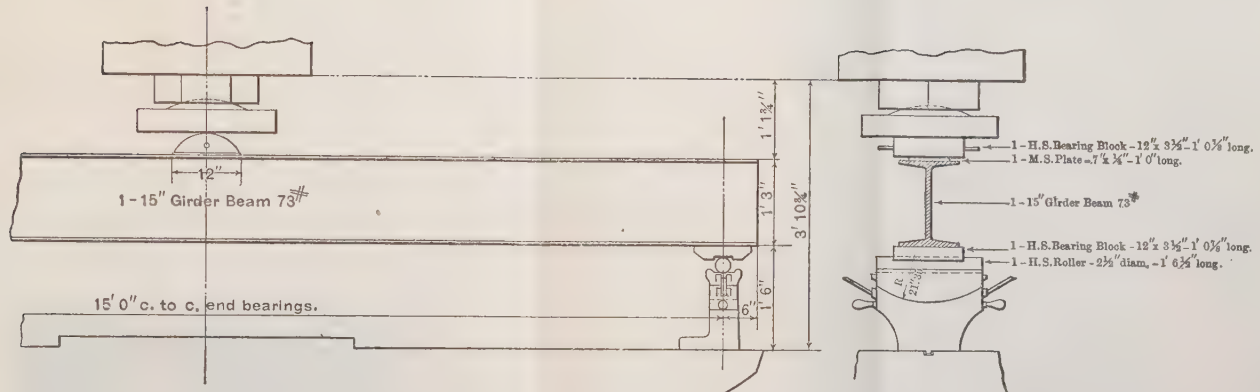
The quarter-point loading was chosen because, for a given total load W and span l , it develops the same maximum bending moment, $\frac{1}{8} Wl$, and maximum shear, $\frac{1}{2} W$, as in a beam of like span subjected to the same load uniformly distributed. The conditions in the former case are more severe, however, since the maximum bending moment exists throughout the middle half, and the maximum shear throughout the two end quarters, whereas in the latter these maximum effects are produced only at the central and end sections respectively.

Mountings.—The mountings are shown in detail in Figs. 8 and 9, Plate II, the former for central, the latter for quarter-point loading. The ends rested on hardened-steel rollers, admitting of free movement under deflection and longitudinal deformation. These rollers were supported on closely fitted segmental end bearing blocks, a , b , Fig. 9, the cylindrical bearing between these blocks being lubricated so that the supports could adjust themselves freely to any slight lack of parallelism of the flanges due to initial wind in the web or other causes. Very careful observation showed, however, that such movements occurred only during the application of initial loads of a few thousand pounds. During subsequent stages of the tests no angular movement whatever was discernible in these supports, except in certain cases, after failure by the twisting of the web, when the horizontal component of the end shear on the inclined web produced a sufficient thrust to overcome the friction on the cylindrical bearings. The movement of the rollers resting on the end supports was outward, since the elastic stretch of the lower flanges exceeded the opposite influence of the deflection. In the tests of the three 30-in. girder beams, the lower end block, b , was removed entirely and the upper block, a , was allowed to rest directly on a flat hardened-steel plate placed on the grooved plate c , as seen also in Fig. 10.

In the tests of the 15-in. beams, the end bearings were mounted directly on the bending table attached to the machine, as shown in Fig. 8. This table having a capacity of only 200,000 lbs., the increased requirements for the tests of the 24 and 30-in. beams were met by placing a temporary table, consisting of a pair of 30-in. Bethlehem girder beams, 175 lbs., on the central platform of the machine, as shown in Fig. 9.

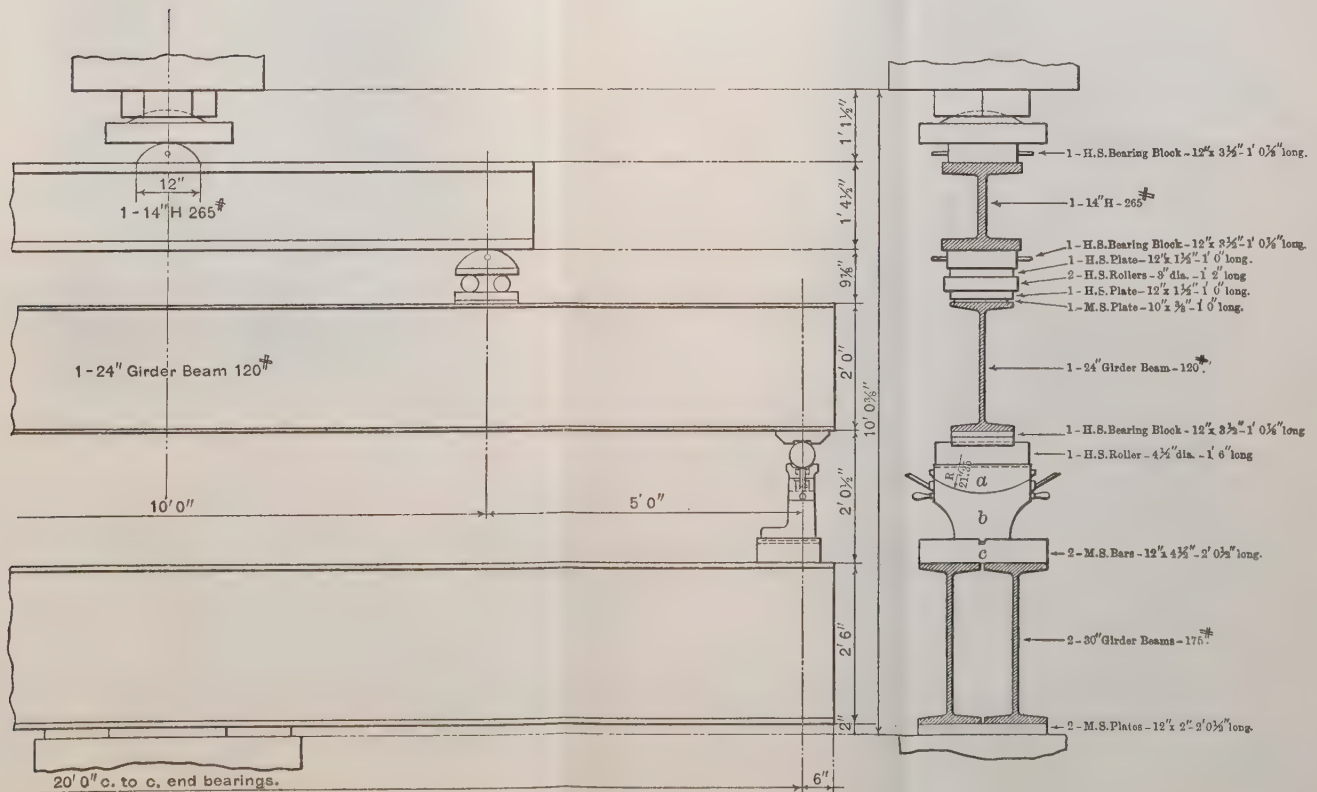
The load was applied by means of a 600,000-lb. Olsen testing machine, through a spherical bearing block with a flat lower surface acting upon the cylindrical surface of a segmental block of hardened steel. Similar blocks, supported on hardened-steel rollers, served for the development of the loads at the quarter-points, as shown in Fig. 11.

Measuring Apparatus.—The vertical deflections at the center were measured in the following manner. A 6 x 1-in. board of white pine, 16 ft. long, stiffened laterally by a 2 x 1-in. strip screwed to its lower edge, was supported edgewise on studs clamped to the beam at the ends, in the neutral plane, directly above the end rollers. For measurements on 20-ft. spans, wooden extension pieces were provided at the ends, as seen in Fig. 10. The stud at one end passed through a round hole, and that at the other through a horizontally-slotted hole in the board. A polished steel scale, reading directly to 0.01 in. was attached vertically to the web, at the center of the beam. A finely pointed metal strip, screwed to the board at its center, longitudinally, with its outstanding point nearly touching the steel scale, was used in reading deflections on the latter. To avoid parallax the pointer was split, one point being bent back about 2 ins. It was found more satisfactory to use the line of these two points in taking readings than the indistinct reflection in the polished scale of a single point in connection with that point. In the numerous observations taken under released and re-applied loads, accordant readings to the nearest 0.01 in. were invariably obtained, and in some of the later tests these readings were made to the nearest 0.005 in. The use of a pointer on a board instead of the usual wire eliminated the liability of disturbances due to changes in the deflection of a long wire under slight variations in tension. Various other means of determining deflections by more refined methods were tried and discarded in favor of that described, which



Details of Mounting 1-15" Girder Beam for Single-Point Loading.

FIG. 8.

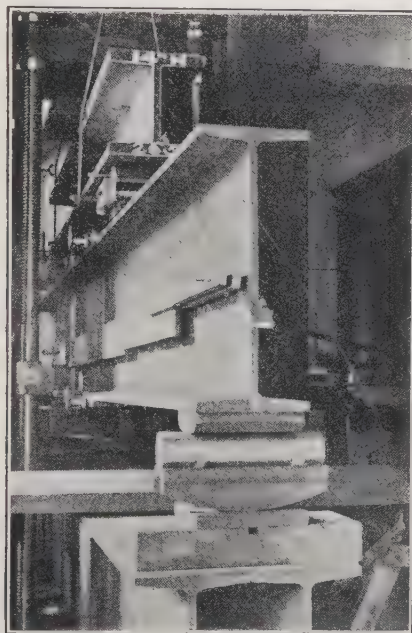


Details of Mounting 1-24" Girder Beam for Two-Point Loading.

FIG. 9.

commended itself by its extreme simplicity, its positiveness, and its accuracy within sufficiently close limits for the purpose in view.

In all of the tests under quarter-point loading, the fiber deformations were observed by means of four Johnson dial extensometers attached in the planes of the outer fibers, top and bottom, and on opposite sides of the beam, as shown in Fig. 11. The read-

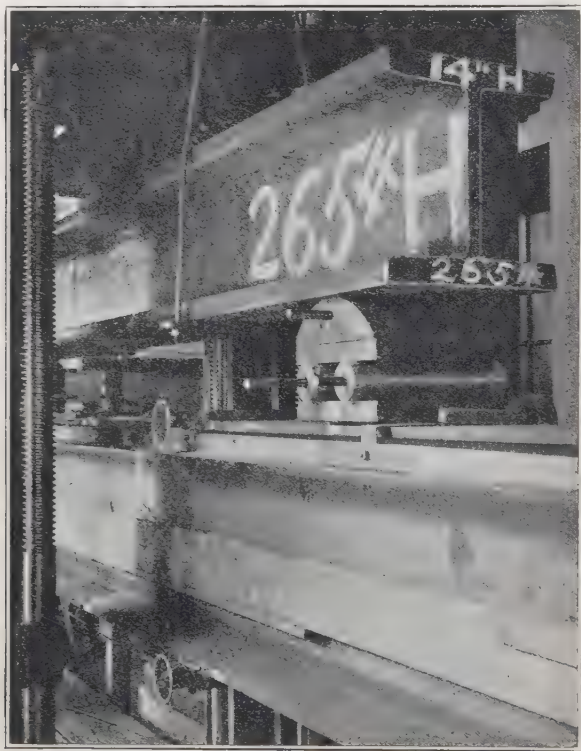


Beam G 32, 30-in., 175 lb., before testing.

FIG. 10.

ings were taken on a gauge length of 40 ins., along the central half-length of the beam for which the intensity of fiber stress was constant. The spindle to which the indicator was attached was rotated by the frictional contact of longitudinal bars slightly weighted at the ends. The readings were taken, at first, to the nearest 0.0001 in., but later only to the nearest 0.001 in. As the loads in the earlier stages of a test were alternately released and re-applied with a view of determining the first permanent set in

the vertical deflection, it was found that these dials could not always be relied upon for accordant readings. The substitution of wire for the contact bars did not remedy this difficulty. Accordingly, after a load had been released, a return was always made to the same load, the dials read, and re-set if necessary, before adding the



Details for Quarter-Point Loading.

FIG. 11.

next load increment. The four dials were first calibrated by means of a Browne and Sharp micrometer, and were found correct within errors of less than 1 per cent.

In the earlier tests the attempt was made to observe the lateral deflection of the upper flange by clamping a longitudinal bar—a light flat or angle—along the side of the flange, as shown in Fig. 20, and reading the deflection to the nearest 0.01 in.

TABLE III.—BENDING TESTS OF 15-IN. BEAMS, CENTRALLY LOADED, SPAN 15 FT.

Lab. No.	Type.	Size.	At Elastic Limit.			Modulus of Elasticity in 1,000,000 lbs.	Load at Ultimate Strength, lbs.			Modulus of Rupture, lbs. per sq. in.		Principal Manner of Failure.
			Load, lbs.	Deflection, ins.	Fiber Stress, lbs. per sq. in.		W	W'	K	K'		
B1	Beth. I	15 in.-38 lb.	49,000	0.50	36,300	26.9	51,000	58,500	37,800	43,300	Twist of Web.	
B2	"	"	35,000	0.35	26,000	27.5	60,000	63,300	44,500	46,900		
B3	"	"	44,000	0.46	32,700	26.3	59,800	64,900	44,300	48,190		
S4	Std. I	15 in.-42 lb.	29,000	0.28	21,700	26.1	50,000	56,750	37,200	42,100	Lateral deflection of Top Flange.	
S5	"	"	27,000	0.27	20,200	26.3	52,000	56,600	38,600	42,000		
S6	"	"	26,000	0.26	19,400	26.3	53,000	57,300	39,400	42,600		
G7	Girder	15 in.-73 lb.	72,000	0.36	26,700	27.4	137,700	146,000	50,900	53,900	Wavy buckling of Top Flange near center.	
G8	"	"	74,000	0.38	27,400	26.7	136,000	146,250	50,300	54,000		
G9	"	"	70,000	0.36	26,000	26.7	130,000	145,200	48,000	53,700		
Average Values:												
Beth. I			42,700	0.44	31,700	26.9	56,900	62,200	42,200	46,100	NOTE: W = Load at First Lateral Deflection. W' = Load at Ultimate Strength. K = Modulus of Rupture for Load W. K' = " " " "	
Standard I	.....	.....	27,300	0.27	20,400	26.2	51,700	56,900	38,400	42,200		
Girder	.....	.....	72,000	0.37	26,700	26.9	134,600	145,800	49,700	53,900		

TABLE IV.—BENDING TESTS OF 15-IN. BEAMS, LOADED AT QUARTER POINTS, SPAN 15 FT.

Lab. No.	Type.	Size.	At Elastic Limit.				Load at Ultimate Strength, lbs.	Modulus of Rupture, lbs. per sq. in.	Principal Manner of Failure.
			Load, lbs.	Deflection, ins.	Fiber Stress, lbs. per sq. in.	Modulus of Elasticity in 1,000,000 lbs.			
			w	Δ	S	E	W	K	
B10	Beth. I	15 in.-38 lb.	65,000	0.46	25,000	26.6	98,000	37,600	Twist of Web.
B11	"	"	45,000	0.33	17,400	25.7	99,000	38,000	"
B12	"	"	60,000	0.42	23,100	27.0	99,000	38,000	"
S13	Std. I	15 in.-42 lb.	55,000	0.38	21,300	25.8	85,900	33,000	Lateral defl. of Top Flange.
S14	"	"	50,000	0.34	19,300	27.8	92,900	35,700	"
S15	"	"	55,000	0.37	21,300	27.0	91,800	35,300	"
G16	Girder	15 in.-73 lb.	130,000	0.45	25,000	26.2	220,800	42,200	"
G17	"	"	110,000	0.38	21,200	27.3	207,000	39,600	"
G18	"	"	110,000	0.37	21,200	28.0	217,500	41,600	"
Average Values:									
Beth. I.			56,700	0.40	21,800	26.4	98,700	37,900	Twist of Web.
Standard I.			53,300	0.36	20,600	26.9	90,200	34,700	Lateral defl. of Top Flange.
Girder			116,700	0.40	22,500	27.2	215,100	41,100	"

TABLE V.—BENDING TESTS OF 24-IN. BEAMS, LOADED AT QUARTER POINTS, SPAN 20 FT.

Lab. No.	Type.	Size.	At Elastic Limit.				Load at Ultimate Strength, lbs.	Modulus of Rupture, lbs. per sq. in.	Principal Manner of Failure.
			Load, lbs.	Deflection, ins.	Fiber Stress, lbs. per sq. in.	Modulus of Elasticity in 1,000,000 lbs.			
			w	Δ	S	E	W	K	
19	Beth. I	24 in.-72 lb.	115,000	0.39	20,000	26.5	186,000	32,300	Twist of Web.
20	"	"	145,000	0.47	25,200	28.7	205,000	35,500	"
21	"	"	100,000	0.38	17,500	24.1	207,000	35,900	"
S22	Std. I	24 in.-80 lb.	120,000	0.43	21,000	23.7	190,000	33,000	Lateral defl. of Top Flange.
S23	"	"	115,000	0.39	20,100	25.5	190,000	33,000	"
S24	"	"	100,000	0.34	17,500	28.3	189,500	32,900	"
G25	Girder	24 in.-120 lb.	200,000	0.43	20,100	23.7	355,000	35,400	"
G26	"	"	120,000	0.25	12,100	26.2	333,000	33,300	"
G27	"	"	140,000	0.28	14,100	26.8	345,000	34,400	"
Average Values:									
Beth. I.			120,000	0.41	20,900	26.4	199,000	34,600	Twist of Web.
Standard I.			115,000	0.39	19,500	25.8	189,800	33,000	Lateral defl. of Top Flange.
Girder			153,000	0.32	15,400	25.6	344,300	34,300	"

TABLE VI.—BENDING TESTS OF 30-IN. BEAMS, LOADED AT QUARTER POINTS, SPAN 20 FT.

Lab. No.	Type.	Size.	At Elastic Limit.						Principal Manner of Failure.	
			Load, lbs.	Deflection, ins.	Fiber Stress, lbs. per sq. in.	Modulus of Elasticity, in 1,000,000 lbs.				Modulus of Rupture, lbs. per sq. in.
						Load at Ultimate Strength, lbs.				
			w	Δ	S	E	W	K		
B28	Beth. I	30 in.-120 lb.	150,000	0.175	13,000	29.4	376,000	32,300	Twist of Web.	
B29	"	"	Beam rejected on surface inspection							
B30	"	"								
G31	Girder	30 in.-175 lb.	190,000	0.18	11,100	25.2	474,000	27,400	Twist of Web.	
G32	"	"	185,000	0.195	10,800	23.9	572,000	33,000	"	
G33	"	"	230,000	0.23	13,400	25.2	569,200	32,800		
Average Values:										
Beth. I.			Only one beam tested.							
Girder			201,700	0.202	11,800	24.8	538,400	31,000	Twist of Web.	

by means of graduated wedges inserted at any desired point between the outstanding edge of the flange and the longitudinal bar. It was found that slight, irregular movements occurred during the early stages of loading while the beam was apparently adapting itself to its bearings. No subsequent movements were then discernible until the elastic limit of the beam had been exceeded and usually not until the ultimate strength had been nearly reached, as may be seen from a comparison of the loads w , W , and W' in Table III. Since these measurements were very time-consuming, and appeared to furnish little or no useful information, they were omitted in the later tests. The records of these measurements in connection with the earlier tests are not regarded as of sufficient value for reproduction.

Elastic Limit.—The values of the elastic limit in bending given in Tables III to VI inclusive, are the computed extreme fiber stresses for the loads above which the load-deflection ratio ceases to remain constant, as seen in Figs. 12 to 15, inclusive, Plates III, IV, and V. In these figures, the points at which the first permanent set was observed, and the limits within which that set remained constant, are indicated, as well as the corresponding extreme fiber stresses. As a measure of extra precaution, after a load had

been released in order to take observations for permanent set, a return was always made to that load, and the deflection re-read before applying the next load-increment. As indicative of the satisfactory performance of the apparatus, previously described, it may be said that in the hundreds of readings thus repeated not a single discrepancy was observed. In the case of beam B 2, Fig. 12, the load was carried to such a point before it was released for observations of permanent set that the latter had already ensued. The load at which it first occurred was therefore uncertain, and could not be recorded. For beams B 11 and B 12, Fig. 13, and G 27, Fig. 14, the load corresponding to the elastic limit, as above defined, is slightly less than that which produced the first permanent set; for beams G 18, Fig. 13, G 26, Fig. 14, and B 28 and G 32, Fig. 15, these two loads are identical; for the remaining 24 beams of the 31 tested, the elastic-limit load is greater, and in some cases very much greater, than the permanent-set load.

The fiber stresses at the elastic limit can be conveniently compared by reference to Tables III to VI inclusive, where the average value for each group of beams is also given; but the best survey of the entire field may be had from Fig. 16, in which the individual values for each group are plotted on a descending scale. The following are the most important deductions from this diagram:

1. That the elastic limit of the standard beams is very nearly constant, the average value lying slightly above 20,000 lbs.
2. That the elastic limit of the Bethlehem special I beams is much lower for quarter-point than for central loading, and that this is true also, though in a less degree, of the girder beams. A partial explanation may, perhaps, be found in the fact that with the former loading, the maximum fiber stress is developed throughout the middle half of the beam instead of at the central section only; although this applies equally to the standard beams, which exhibit no such difference in their behavior.
3. That the elastic limit of the 15-in. Bethlehem beams is much higher than that of the 15-in. standard beams, under central loading, and slightly higher under quarter-point loading.
4. That the elastic limit of the Bethlehem beams declines very rapidly for the larger sections, reaching finally the remarkably low value of 10,800 lbs. for the 30-in. girder beam G 32, the values for the other two beams of that set being only slightly higher.

The elastic limits of the 30-in. Bethlehem beams are so surprisingly low that they merit more detailed consideration. On reference to the load-deflection diagrams of these four beams, Fig. 15, it is seen that for G 31 and G 33, they show a slight curvature, even below the elastic limit, and that by the most liberal interpretation no higher values than those designated

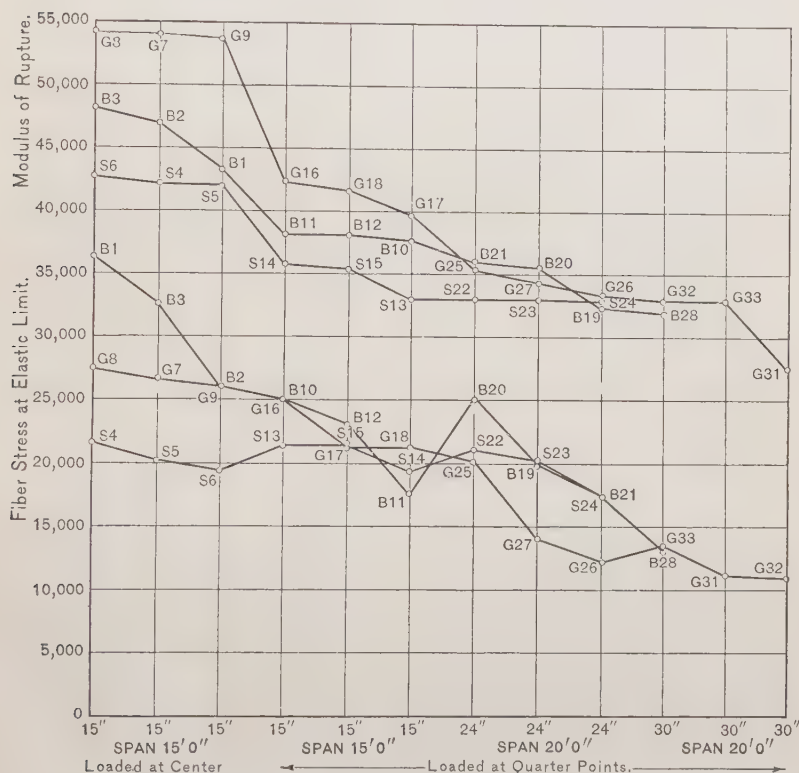


FIG. 16.—Moduli of Rupture and Elastic Limits.

can be assigned to the elastic limit. It is also seen that permanent set was observed in each case at or below the load corresponding to the elastic limit. As previously stated, the girder beams were mounted on cylindrical bearings resting on flat plates, Fig. 10, to admit of their better adjustment to any irregularities in the beams. This circumstance can not account,

however, for the low values of the elastic limit; first, because the flanges remained in perfect alignment till shortly before failure, and second, because in the test of the single Bethlehem 30-in. special I beam, B 28, a curved lower bearing block was used, Fig. 23, instead of a flat plate, and yet the elastic limit in this instance, 13,000 lbs., is 400 lbs. lower than that of the 30-in. girder beam, G 33. On the small scale diagram, Fig. 16, these two values appear almost coincident. Further corroborative evidence as to the remarkably low value of the elastic limit of these 30-in. girder beams is to be found in the fiber-deformation measurements performed directly on the flanges themselves, which will receive further attention below. The writer expected to have the opportunity of making additional tests on such beams, mounted on flat end-bearings resting on rollers. In his opinion, this change would, however, have had no effect on the elastic limit, because the alignment of the flanges in these tests was unaffected up to loads far beyond the elastic limit. This is also clearly shown by the close agreement of the fiber-deformation readings on opposite sides of the flanges, Fig. 19, which will be referred to more in detail hereafter.

The writer will hazard no opinion as to the indirect cause of these remarkably low values of the elastic limit; although they are attributable directly to poor material, or inherent shrinkage stresses, or probably to both; but he desires to express his conviction that if the beams tested are fairly representative samples, the use of a working fiber stress of 16,000 lbs. per sq. in., as usually recommended for buildings, is indefensible. It is essential, in his judgment, that the investigation of this phase of the subject should be greatly extended.

Modulus of Rupture.—The computed values of the modulus of rupture are shown on the load-deflection diagrams, as well as in Tables III to VI inclusive. Again, in Fig. 16, the individual values are plotted in the same manner as the elastic limits, that is to say, on a descending scale for each group. The general trend of the two sets of curves is very similar. It is seen that the values of the modulus of rupture in the case of the standard beams exhibit considerable variations, whereas the elastic limits are nearly constant. The Bethlehem 30-in. beams again give the lowest values, beam G 31 having a modulus of only 27,400 lbs.

On reference to Fig. 16, it is observed, also, that under central loading, the Bethlehem special I beams developed much higher elastic limits than the girder beams, whereas the latter exhibited greater moduli of rupture. Again, beam B₁, which has the highest elastic limit, 36,300 lbs., has also the lowest modulus of rupture, 43,300 lbs., of the three beams in that group. The ratio of elastic limit to modulus of rupture is, in fact, very variable, as would be more readily apparent had the values of each been plotted for the beams arranged in the same sequence, instead of on a descending scale for the beams in each group. In the case of beam B₁ the ratio in question has the remarkably high value of 84 per cent.

It may reasonably be anticipated that the modulus of rupture, unlike the elastic limit, is influenced in a no inconsiderable measure by the degree of fixedness of ends, and by the lateral support of the compression flange at intermediate points. The values here given should, therefore, be regarded as relative rather than absolute.

Ratios of Critical Loads.—The ratios of the average critical loads, namely, the loads at the elastic limit and modulus of rupture, in a comparison of the Bethlehem with the standard beams, are given in Table VII.

TABLE VII.

Beams Compared.	Average Ratios of Critical Loads.					
	Elastic Limit.			Modulus of Rupture.		
	15-in. Beams.		24-in. Beams.	15-in. Beams.		24-in. Beams.
	Ctr. Load.	$\frac{1}{4}$ -Pt. Load.		Ctr. Load.	$\frac{1}{4}$ -Pt. Load.	
Beth. I.	1.56	1.06	1.04	1.09	1.09	1.05
Stand. I.						
Beth. Gir.	2.64	2.19	1.33	2.56	2.38	1.81
Stand. I.						

As previously stated, the Bethlehem special I beams have the same section moduli as the standard I beams, and the Bethlehem girders have, in general, twice the section moduli of the latter, comparing always the lightest beams of each type and depth. Referring to Table VII, it is seen that the ratio unity is more than realized by the special beams, and that the ratio 2 is exceeded by the 15-in. girder beams; but that the ratios for the 24-in. girder beams are considerably below 2. It is to be observed, however, that in the case of these beams, the section modulus of the girder

beam is about 11 per cent. less than twice that of the standard beam, as may be seen from Table II.

Comparing the average values for the three 30-in. girder beams with those for the single 30-in. special I beam, the ratios of the loads at the elastic limit and modulus of rupture are found to be 1.34 and 1.43 respectively, whereas the ratio of their section moduli is 1.49.

Modulus of Elasticity.—On reference to Tables III to VI, inclusive, it is seen that the modulus of elasticity in bending is nearly constant, its average value for the 31 beams tested being 26,300,000. The average modulus from the tensile tests, Table II, after rejecting the value 35,000,000 for the abnormal specimen from the root of the 15-in., 73-lb. Bethlehem girder, is 28,700,000, or nearly 10 per cent. higher than the modulus in bending, this difference being in general agreement with observations of a similar nature by other investigators. In the computation of the modulus of elasticity in bending, the effect of the shearing deformations on the deflection was disregarded, as is commonly done in practice. The resulting values are therefore too low, the error involved becoming increasingly marked as the ratio of depth of beam to span increases; but on the other hand, the exact value under the latter conditions is seldom a matter of practical interest, since the total deflections are then themselves small.

Fiber-Deformation Curves.—These curves appear in Figs. 17 and 18, Plate VI, and Fig. 19. For each beam tested under quarter-point loading four curves are shown, representing observations on opposite sides of the upper and lower flanges, distinguished by U and L respectively. The fiber stresses on these diagrams are all expressed in terms of 1,000 lbs. The load at the elastic limit was determined by averaging the change of slope of each bifurcated line, the corresponding points being indicated by small circles. Some of these curves are quite irregular, but in general they are perhaps as accordant as can reasonably be expected for such observations. The minor irregularities in the lines are partly due to the fact that the readings in most instances were taken to the nearest 0.001 in., instead of 0.0001 in. In a few cases, the readings were not carried far enough to locate the elastic limit.

The fiber stresses whose values are given on the horizontal lines traversing the elastic-limit circles are computed from the

corresponding loads by the common formula of flexure. The values above and below this one in Figs. 18 and 19, are found by multiplying the average unit deformation of each flange at the elastic limit by the moduli of elasticity in bending and tension (flange specimen) respectively, the former being that found for each beam individually, and the latter the single value for all beams of the same group. Since no tensile records for the flange specimens of the 15-in. beams are available, for reasons previously stated, the lowest of the three values is omitted throughout Fig. 17.

Finally, for convenience of comparison, the fiber stress corresponding to the elastic limit in bending is in each case indicated by a cross-line. In the great majority of cases, this is lower than that based directly on the recorded fiber deformations. No attempt will be made to enter upon a detailed analysis. Referring, however, to the curves for the 30-in. Bethlehem girder beams, Fig. 19, which exhibited such low elastic limits in bending, e. g., 10,800 lbs. in the case of G 32, it is seen that the average elastic limit of this beam, based on direct fiber deformations of the upper and lower flanges, has the value $\frac{1}{2}(13,400 + 8,800) = 11,100$ lbs., or practically the same as the above value in bending. It is also seen that the readings on opposite sides of both the upper and lower flange are substantially in agreement for the entire range of observations, thus showing conclusively the absence of lateral deflection of the flanges.

The diagrams in Figs. 17 to 19 inclusive give no indication as to the respective sides of the flanges on which the recorded deformations were observed. Obviously, if the deformations are greater on opposite sides of the two flanges, that condition would be indicative of a twisting tendency; whereas, if the deformations are greater on the same side of both flanges, that would point to lateral bending of the beam as a whole. Designating these opposite conditions as Case I and Case II respectively, the observations on the 22 beams tests under quarter-point loading may be grouped as follows:

Case I, B 12-19-20-21-28, S 23-24, G 18-26-31-32-33..	12
Case II, G 17	1
Case I followed by Case II, B 11, S 15, G 27.....	3
Case II followed by Case I, B 10, S 14-22, G 25.....	4
Case I followed by Case I reversed, S 13, G 16	2

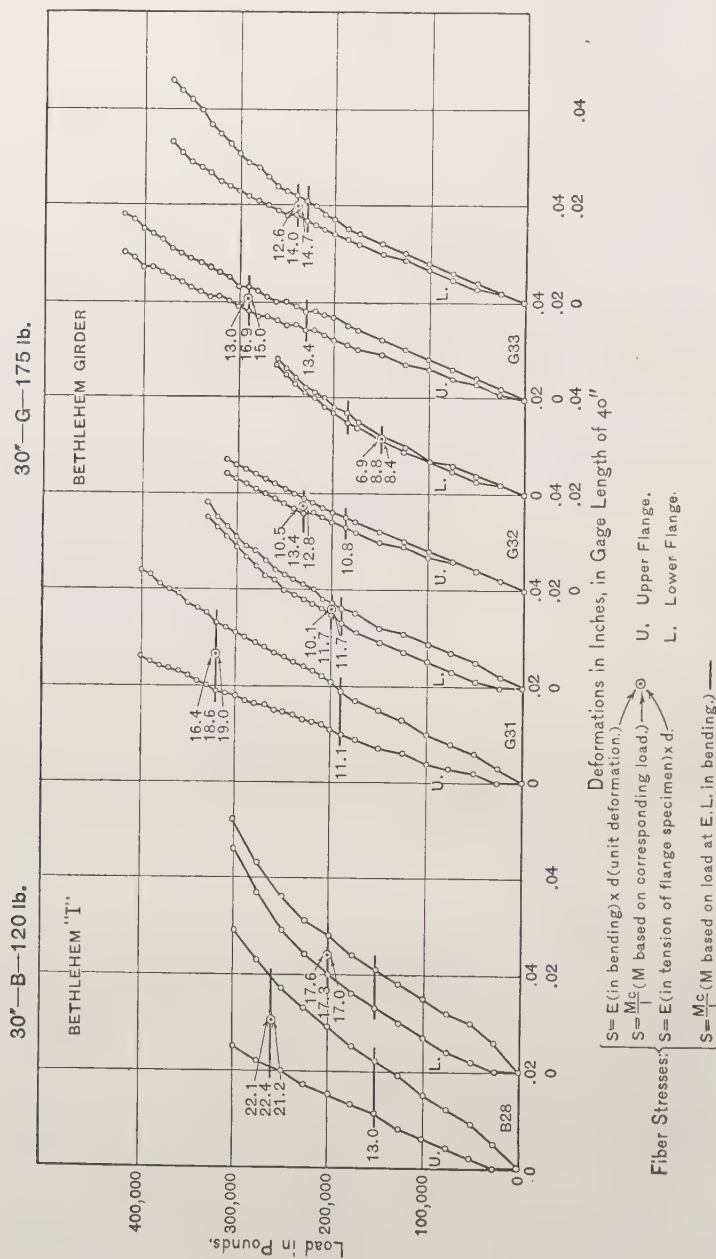


FIG. 19.—Fiber-Deformation Curves, 30-in. Beams.

In many instances, especially within the elastic limit, the readings on opposite sides of the same flange are in such close agreement as to render the above distinctions comparatively meaningless. The marked preponderance of the conditions designated as Case I, or a twisting tendency, might have been anticipated, since that effect would be produced by any influence causing a departure from the perfect centering of the loads and reactions, in the vertical plane of symmetry of the web and flanges. A like effect would be produced by the departure of the web from true verticality. For beams in service, the same result would manifestly be brought about by eccentric loading from any cause. The extent to which rigid end connections would serve to counteract the effect of such twisting action, especially under the relatively slight movements within the elastic limit, must be regarded as an open question. It is obvious, however, that the development of such twisting moments is practically unavoidable, both under laboratory and service conditions.

Shearing Stresses.—The maximum shearing stress developed in each beam is half the ultimate load, Tables III to VI inclusive, increased by its half-weight. These maximum shears, in terms of 1,000 lbs., are approximately:

Depth, ins.	Beth. I.	Standard.	Girder.
15	50	47	111
24	104	96	179
30	189	...	288

The maximum safe shears, according to the hand-book issued by the Bethlehem Steel Company, based on the formula,

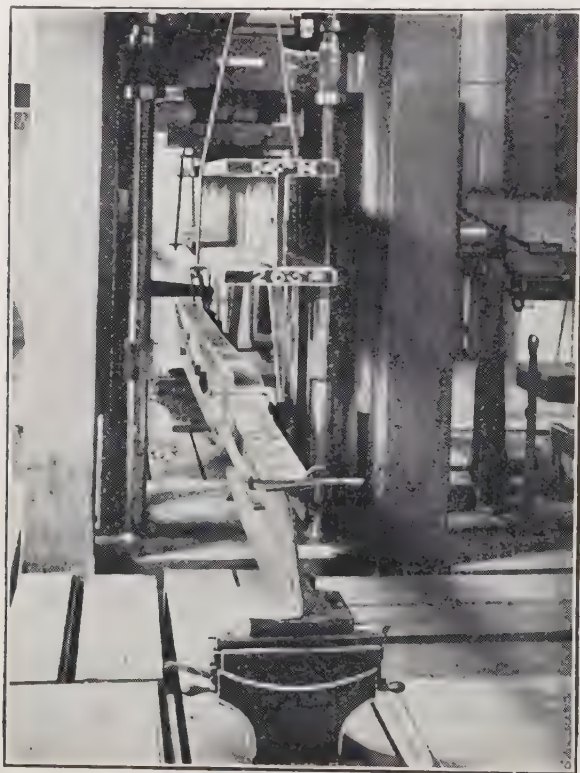
$$\text{Shear} = \frac{12,000 \, dt}{1 + \frac{h^2}{3000 \, t^2}}$$

in which d is the depth of beam, t the web thickness, and h the clear depth between flanges, have the following values in terms of 1,000 lbs. for the Bethlehem beams under consideration:

Depth, ins.	Beth. I.	Girder.
15	28.4	57.6
24	48.9	93.0
30	97.4	163.3

These values are, with one exception, slightly more than half as great as the maximum shears developed in these tests. As

already observed, none of the beams in the present series of tests failed by local crippling of the web. It is claimed, on the basis of a few tests on small beams, that the values derived by the above formula have a safety factor of from 3 to 4 with respect to the shear which would produce crippling.



15''-S-42-1b. Beam, after failure.

FIG. 20.

Manner of Failure.—The principal manner of failure of each beam is described briefly in the last column of Tables III to VI inclusive. The standard beams failed in every instance by what is described as “lateral deflection of top flange,” and the Bethlehem special I beams by what is designated “twist of web.” Manifestly any lateral movement of the flange is accompanied by a

like movement of the web. The distinction in the two forms of designation is made, however, because in the case of the standard beam the initial cause of failure seemed to be the lateral weakness of the compression flange; that is to say, while the flange would deflect laterally near the center, the verticality of the web at the

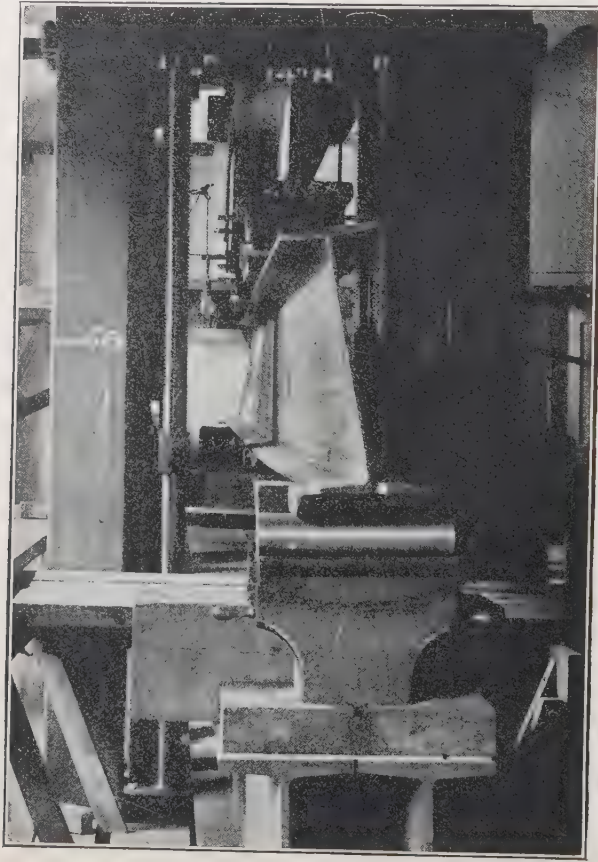


15"-S-42-lb. Beam, after failure.

FIG. 21.

ends would be well maintained (see Figs. 20 and 21), unless the bending of the beams was continued, under rapidly decreasing loading, far beyond the point at which the load had reached its maximum value. The failure of the Bethlehem special I beams was, on the contrary, generally speaking, marked by a sudden and

considerable twisting of the web—usually in opposite directions at opposite ends, the beam as a whole assuming the form of a very flat letter S—the flanges remaining comparatively straight, as may be seen in Figs. 22 and 23, showing 24 and 30-in. beams after failure.

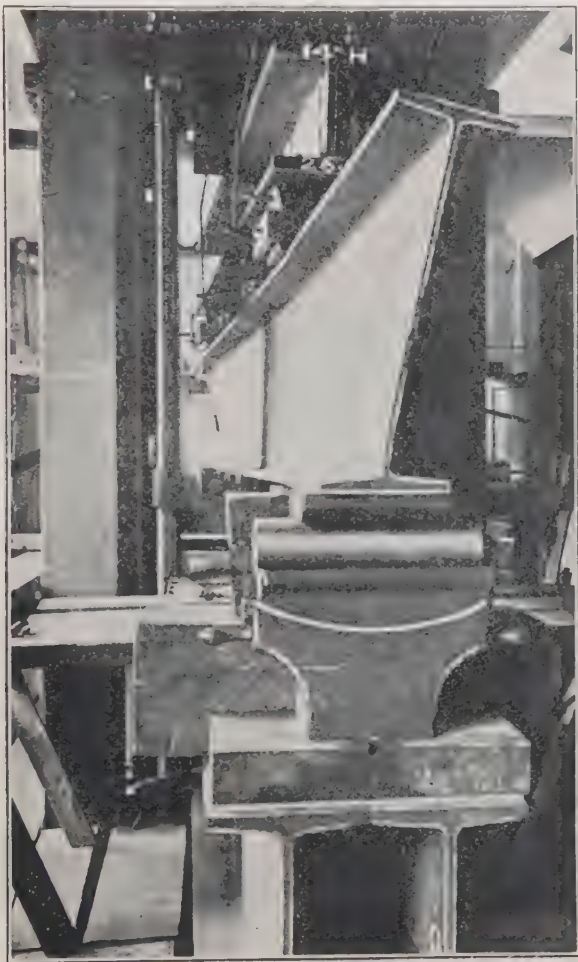


24''-B-72-1b. Beam, after failure.

FIG. 22.

The characteristic failure of the 15 and 24-in. Bethlehem girder beams, under quarter-point loading, was by the lateral deflection of the upper flange, in a manner very similar to that of the standard beams. Owing to the greater width of flange

in these beams, this deflection, once begun, did not increase as rapidly as in the case of standard beams. The 30-in. Bethlehem



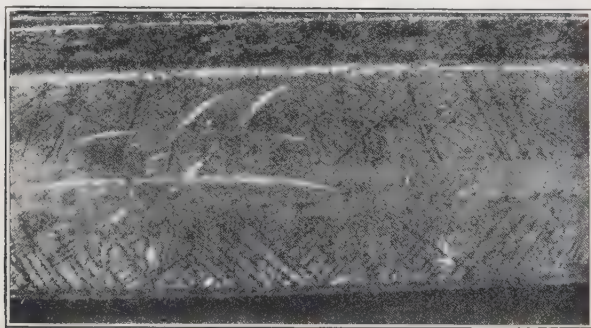
Beam B 28, 30-in., 120 lb., after failure.

FIG. 23.

girder beams failed by the twisting of the web. The 15-in. girder beams, centrally loaded, failed, on the contrary, by the wavy buck-

ling of the outstanding edges, vertically, in the vicinity of the center, the metal being apparently too thin to bring about failure through the lateral deflection of the compression flange. When this form of failure began to manifest itself, there was no evidence of any lateral deflection of the flange as a whole. From the details of the mounting of the 15-in. girder beams under central loading, Fig. 8, Plate II, it is seen that the load was applied through a plate 7 ins. wide, resting on the top flange. Since the flanges are $10\frac{1}{2}$ ins. wide, the edges projected to a width of $1\frac{3}{4}$ ins.

In general it may be said that there was in no instance any evidence of the buckling of the web in detail vertically, not even at the points of loading and support. The web in twisting assumed



Lines of Principal Stress.

FIG. 24.

the curvature of a warped surface, that is to say, its originally vertical elements became inclined, but remained straight, or grew very slightly curved, as was apparent on the application of a steel straight-edge to the webs after the beams had failed.

The characteristic lines of principal stress as developed by the flaking of the mill-scale are shown in Fig. 24, which represents that part of the beam in the immediate vicinity of the point at which the load was applied. This photograph was taken after the markings had been brought out sharply by the rusting of the beam on exposure in the open air. The lines along the lower flange slope at angles of about 45° with the horizontal, which is theoretically the correct angle for the lines of maximum shear at the outer fibers. The lines of principal stress along the upper

flange show the influence of the local concentration of the load. Here the direction of the principal lines is nearly vertical, sloping slightly away to either side from the point of application of the load. There is visible also a net-work of finer lines, sloping at an angle of about 45° with the horizontal.

Conclusions.—The number of tests are not sufficient to warrant definite conclusions. They do point out the need, however, of greatly extended investigations along these and other lines, with a view of throwing more light on the following points in particular:

1. The low elastic limit of the metal near the root of the flange: its cause and prevention.

2. The low elastic limit in bending of the deeper beams: its cause and prevention.

3. The behavior of beams under protracted loading of a magnitude equal to or slightly greater than the elastic-limit load.

4. The effect, both on the elastic limit in bending and modulus of rupture, of variations in the supports and lateral restraint at the ends and intermediate points.

5. Extensive tests on the crippling strength of thin webs.

6. An experimental inquiry relative to the existence and magnitude of internal stresses, and how these are affected by different methods of rolling, finishing-temperature, etc.

In conclusion, the writer has the pleasure of expressing his appreciation of the able and zealous assistance rendered by Mr. H. C. Berry, Assistant Professor of Materials of Construction, and Mr. George Rosengarten, Instructor in Civil Engineering at the University of Pennsylvania, in connection with these tests. The writer witnessed all the bending tests with two exceptions, and the majority of these tests were witnessed also by one or more representatives of the Bethlehem Steel Company. The tensile tests were made and witnessed only by Professor Berry and Mr. Rosengarten, who also performed separately all the computations needed in the preparation of the data here presented.

DISCUSSION.

Mr. Merriman.

MR. MANSFIELD MERRIMAN.—It would be difficult to discuss the technical features of this paper without giving it careful study. It is evident, however, that great care has been taken in making these experiments, and that the discussion of them in the paper is very thorough, so that the results are of great value. We find here what has often been found before, when tests are made upon full-size members, that the strength is not so great as had been previously supposed. It is very much to be desired that college laboratories, assisted if possible by the manufacturers as was done in this case, should make experiments upon full-size members which are used in the various branches of engineering practice. Money for the purpose of buying testing machines for a college is often easily raised, but an endowment which shall furnish money for doing research work in the laboratory is very difficult to obtain. If such endowments can be secured it would be to the advantage of the engineering profession. Detailed tests of the strength of steel rails are especially needed.

A Member.

A MEMBER.—I am very much impressed with the importance and value of these tests. I would like to see them carried somewhat further. It would doubtless be an expensive matter, but one whose importance the manufacturers of I beams should recognize by making certain researches on beams beyond the proportions that would be suitable in practice. It would be very desirable, for example, to make tests on beams having a certain fixed thickness of web and span, but with flanges of varying width and thickness.

Mr. Christie.

MR. JAMES CHRISTIE.—The conditions attending the rolling and cooling of the ordinary I beam during its manufacture are such that we cannot expect normal behavior from the material at all points of the section, especially from material that has been recently rolled. When rolling from the bloom by the ordinary process, the material forming the web is more rapidly drawn than that of the flanges during the initial passes, and at the final passes the material of the flanges is more rapidly reduced than that of the

web. When the metal is in a plastic condition, due to its working heat, it is probable that this unequal reduction has no objectionable effect on the finished beam. If, however, the web should be rolled very thin as compared to the flanges, and the web cools or blackens before rolling is completed and ceases to be truly plastic, it may remain under considerable tensile stress. Mr. Christie.

A more serious disturbance occurs when the beam is cooling after the rolling is completed, especially in sections whose web is much thinner than the flanges. In these, the rapidly cooling web tends to pull and compress the more plastic flanges, followed by a reverse action when the flanges finally cool, thus subjecting the parts of the web that forms the junction with the flanges to a severe double stress before cooling is completed. That conditions as here indicated occur, we know from the behavior of unsymmetrical sections, which curve first in one direction and then bend in the opposite direction, at the end of the cooling stage. Furthermore we know that internal or unequal stresses remain in the finished beam, because if the beam is split longitudinally through the middle of the web, the two parts will frequently curve in opposite directions. Consequently in the finished beam we have two abnormal conditions: one due to the method of rolling, possibly of small significance; the other a more serious one, due to unequal cooling; and these may account for the poor results obtained in the tests from the metal in the web adjoining the flanges.

It has been urged that internal stresses, such as those denoted, tend to disappear in time, as they must exist to some extent in all rolled bars irrespective of the shape of the section, the thicker the section, the more obvious the inequality; but it is doubtful if these internal stresses would exercise a seriously prejudicial effect on the resistance of the beam as a whole, as its behavior is so largely influenced by the flanges alone.

I have had frequent opportunities to observe the conduct of I beams subjected to loading considerably in excess of those given as the greatest safe loads in the tables of the manufacturers, and can recall no instance where these tables appeared to be other than trustworthy.

MR. EDGAR MARBURG.—The question of inherent initial stresses is undoubtedly one of great importance. As stated in the Mr. Marburg.

Mr. Marburg. paper, it is perhaps to be anticipated from the difference in the methods of rolling that in the Bethlehem beams such stresses are less pronounced than in the standard beams. However, that can be determined conclusively only by actual comparative tests. That might be done, as pointed out in the paper, by subdividing a short beam into longitudinal strips, both along the flanges and the web. By making extensometer measurements between fixed contact points along these strips before and after they are separated from the beam, the difference in these measurements will indicate both the character and the magnitude of such initial stresses. In other words, the inner history of the material would be revealed by such double measurements.

As to the effect of age in partially relieving these initial stresses it is difficult to see why any such effect is to be expected, provided the initial stresses lie within the elastic limit of the material. Beyond that limit a gradual progressive yielding, resulting in a partial redistribution of the internal stresses, is conceivable. The Bethlehem beams were necessarily of recent manufacture. The history of the standard beams is not known to me. They were purchased by the Bethlehem Steel Company in the open market.

In reply to Mr. Christie's remarks concerning the observed behavior of beams under loads considerably higher than their safe loads according to the hand-books, it is to be remembered that the very low values in these tests were observed only in connection with beams of presumably much greater depth than those to which Mr. Christie alludes. Moreover, in the absence of precise measurements, the loads in question may have developed fiber stresses in excess of the elastic limit without visible evidence to that effect.

Mr. Thackray. MR. G. E. THACKRAY.—In view of the fact that possibly the large majority of beams used to-day are those less than 15 ins. in depth, why was not an attempt made to make comparative tests between these smaller sizes, rather than to confine the tests to 15, 24, and 30-in. beams?

Mr. Marburg. MR. MARBURG.—The tests were made on comparatively deep sections because these constitute by far the largest tonnage of the Bethlehem mill. Moreover, it was thought that the comparative behavior of the 15-in. beams would probably be fairly indicative of that of smaller sections.

MR. THACKRAY.—When further tests are conducted, I would suggest a more complete arrangement of sizes. The narrow-flange beams are what are called “standard” and were designed some fifteen years ago by consultation amongst manufacturers with the idea of maintaining a uniform section, something after the fashion of the then new designs of rails, which had been recently formulated by the American Society of Civil Engineers. Mr. Thackray.

In considering the tests in question, attention ought to be called to the fact, that standard beams in use are designed, and it is so stated in the printed publications of the makers, to have lateral supports at distances not exceeding certain lengths for different sizes and arrangements, and under these conditions the standard beams, I believe, would not fail in the manner shown by the tests in question. The testing of a beam irrespective of lateral support, is one thing; but in testing it under conditions of use for which it is designed, this matter of lateral support must surely be taken into account. I also notice that the end supports were of a yielding character, which is never the case in practice; this introduces further complications into the tests and makes them different from the conditions of use. I can readily foresee that in the testing of beams it would be difficult to provide all the forms of support which are applied in practice. Still these considerations must be borne in mind in interpreting results of the tests.

MR. MARBURG.—In a detailed analysis of the observations made in connection with the 30-in. Bethlehem girder beam G₃₂ which gave the lowest elastic limit, 10,800 lbs., of the entire series, it is shown in the paper that the extensometer readings on opposite sides of both flanges were in substantial agreement up to loads far above the elastic limit, thus indicating conclusively the absence of lateral bending in the flanges. In my opinion the elastic limit would not be increased by changes in the end supports or by intermediate bracing in comparison with the conditions under which these tests were made; although the ultimate strength, that is to say, the modulus of rupture, would, perhaps, be somewhat greater under the modified conditions referred to. However, since working stresses are selected with reference to the elastic limit rather than the modulus of rupture, the value of the latter is of secondary importance. Mr. Marburg.

Mr. Thackray. MR. THACKRAY.—Of course it must be understood that any remark that I have made is not in any sense intended by way of criticism. I have only just heard the paper; but I could not help saying a word in passing with regard to conditions of actual use as compared with the conditions under which the tests were made.

Mr. Talbot. MR. A. N. TALBOT.—It would seem that Mr. Marburg is correct concerning the effect of lateral support within the elastic limit under the conditions usually found in practice. To what extent the ultimate strength is affected would depend upon the method of lateral support used.

Mr. Thackray. MR. THACKRAY.—It seems that some of the previous speakers do not admit the importance of lateral support, whereas, other things being equal, it may have a controlling influence on the strength of a long beam, as may be readily understood. A long wooden joist is of no service unless laterally supported by "bridging" braces, floors, etc., and similarly a long steel beam must have lateral supports.

We have recently had before us a somewhat similar example of the value of lateral supports to individual portions of compression members, namely in the lower chord members of the Quebec Bridge. This case is not altogether parallel with the one in question, but according to official reports the individual portions of certain compression members of the bridge were not adequately supported laterally and secured together so that they would act as a unit to give, as intended, the combined value of their sectional areas and the total radius of gyration of the member. Otherwise the failure would not have happened as it did, by the buckling of the individual plates.

Mr. Colby. MR. A. L. COLBY.—I think I voice the sentiments of the majority of the members present who are interested in the manufacture or use of steel in thanking the author for having so carefully laid before us the results of his unbiased investigations. I trust that his suggestion will be adopted, that the comparison of these two forms of structural steel be made the subject of further study, and I hope that, in due course, the results will be presented to this Society, as a supplement to Mr. Marburg's able paper.

NOTES ON TESTS OF STEEL COLUMNS IN PROGRESS AT WATERTOWN ARSENAL.

BY JAMES E. HOWARD.

Three diagrams, Figs. 1 to 3 inclusive, are submitted here-
with showing the results of compression tests on columns of three
types, being those which were in part reported before this Society
at its last annual meeting. The diagrams show the completed

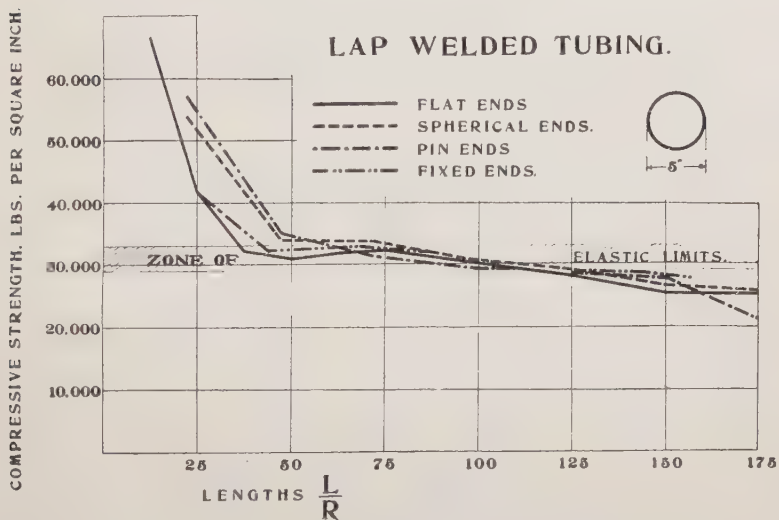


FIG. 1.

series of annular sections, rolled H shapes, and built members
composed of plates and angles.

In addition to the remarks which accompanied the report
of last year but little remains to be said in describing these tests.
The annular sections are represented by four different end con-
ditions: flat, spherical, pin, and fixed; each of the other shapes
being tested with flat and fixed ends only.

On each of the diagrams is plotted a shaded zone, repre-
senting the elastic limits of the material. On two are drawn small

circles showing the ultimate strength of individual tests, the lines on the diagrams representing mean results of three or more tests of the same kind.

It will be noticed that the ultimate strengths generally fall within the zones of elastic limits for ordinary lengths of columns, that is, those which range in length from 50 to 100 l/r . Shorter columns display higher strength, while longer ones fall below this zone. Causes which lead to this result were mentioned upon the occasion of presenting the former report of partial results. It will be noticed, however, that the strength of the shortest

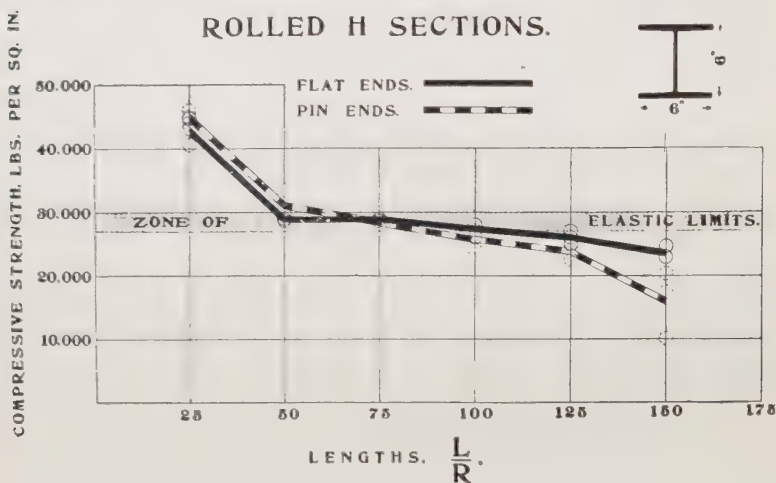


FIG. 2.

columns of the built members did not show that gain in strength which was displayed by the solid rolled or annular sections. The plates and angles of these short columns appeared to act independently rather than as a unit.

The influence of the elastic limit of the material in limiting the ultimate compressive strength is shown in these tests, and also the effect of initial bends in the members in lowering the resistance of long columns in particular. Furthermore, the tests give additional confirmation of the fact, as it is believed to be, that under axial loads the ultimate strength of well made compression members is the same for each of the different types of end bearings.

An improvement in the initial state of the metal of the columns and in the work of fabrication should result in raising the strengths of the columns, in which greater benefits would be expected in the case of the long columns over those gained by shorter ones.

Some additional tests, not comprised in the regular series, were made. Two columns, one with flat ends and one with pins, were tested, in which transverse loads were applied in combination with the direct loads of compression. The transverse loads caused maximum fiber stresses of 15,000 lbs. per sq. in., and were applied at the commencement of the test.

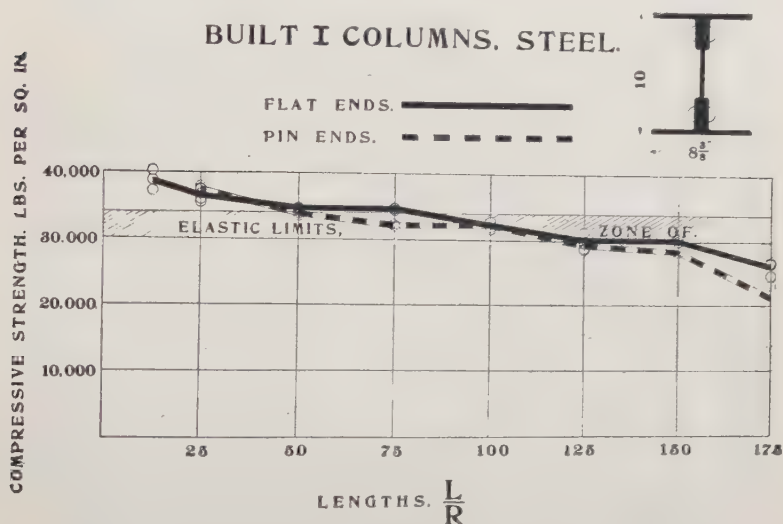


FIG. 3.

A tubular column with flat ends, in length $135 \frac{1}{r}$, under these conditions displayed an ultimate strength of 23,480 lbs. per sq. in., direct compression. The first effect of the direct compressive stress was to cause a decrease in the deflection of the column, after which, as the loads were advanced and approached the ultimate strength, the deflections increased, reaching the amount of 0.66 in. at the time of attaining the maximum load. The total length of the column was 18 ft. 7 ins.

Another tubular column of nearly the same length, being increased by reason of the pin-end fixtures to $140 \frac{1}{r}$, was loaded

in the same manner by a transverse load, causing a fiber stress of 15,000 lbs. per sq. in. Under these conditions, the ultimate strength by direct compression was found to be 9,172 lbs. per sq. in. The deflection at the time of reaching the maximum stress

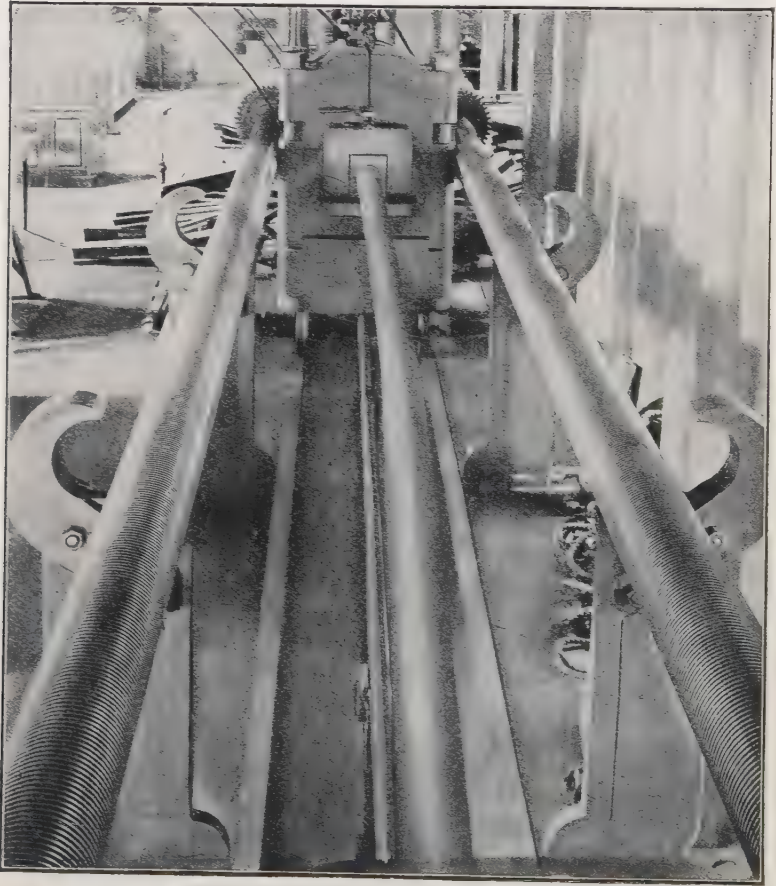


FIG. 4.

was 2.21 ins., the total length of the column being 19 ft. 2 ins. from center to center of 3-in. pins. The deflection of this column was increased until it reached a total of 5.29 ins., when the test was for the time discontinued, the column removed from the testing

machine and straightened cold. It was returned to the machine and retested, with pin ends as before but without the transverse load. Its strength was then found to be 26,110 lbs. per sq. in. The details of these tests will be included in the Arsenal report of Test of Metals.

At the suggestion of Mr. A. W. Carpenter, a third annular column was tested, with flat ends and a length of 150 1/r. The peculiar feature of this column was that it had a joint in the middle, that is, the column was cut in two at the middle of its length and one part rested upon the other. This column had an ultimate compressive strength of 147,000 lbs. total load or 29,280 lbs. per sq. in., which placed it somewhat above that of other columns of this length. After passing the maximum load and when the deflection had reached 2.94 ins., its compressive resistance was 98,000 lbs. total load. Fig. 4 shows the column as it appeared when the test was discontinued, the load then upon it being 98,000 lbs., with the deflection at the middle, 2.94 ins.

DISCUSSION.

Mr. Moisseiff.

MR. L. S. MOISSEIFF.—It would appear from a study of the diagrams of the tests presented by Mr. Howard and of the more numerous tests recently made by him at the Watertown Arsenal, that the effect on the strength of a column due to its ratio of length to radius of gyration, is only slight. Neither the older Rankine-Schwartz formula nor the more recent straight line formula of the American Railway Engineering and Maintenance of Way Association's specifications, agree with the careful tests made by Mr. Howard.

The slight inclination of the line of ultimate strength on the diagrams for all ratios of l/r varying from 40 to 100 clearly shows that the effect of these ratios is small. This leads to the speculation, that for a perfectly symmetrical and straight column made of a perfectly homogeneous material, no reduction at all in the strength of the column would occur, and the curve of ultimate strength would appear as a straight horizontal line. The loss of strength in the columns shown by the tests, is due to lack of homogeneity in the metal, to the local effects of fabrication, and to imperfect straightness. These deterrent causes multiply as the length increases, especially the latter, which is also the most important. Dealing with actual conditions, a gradually increasing reduction in the strength with an increasing length of columns should be allowed for. For this purpose a straight line formula is as near a mathematical device as our imperfect control of conditions will permit. There is no need for more complicated and pretentious formulas, as they do not represent more accurately the physical behavior of columns.

The Watertown tests show, however, that the straight line formulas generally given in specifications and applied by most engineers begin too high and end too low. No column of practical dimensions, allowing for the stiffness of the constituent parts, will develop an ultimate resistance much above the elastic limit of its material. The unit stresses allowed in proportioning short columns should, therefore, be lower than those allowed for

members in tension. This means, in other words, that the unreduced column stress should have a lower value than the tensile stress. The reduction made, however, to allow for the loss in strength with increased l/r should be more gradual than has been considered good practice heretofore. Computed according to the formulas in general use to-day, too high a stress is allowed for short columns and too low a stress for long ones. Mr. Moisseiff.

The Department of Bridges of New York City has, after careful deliberation, arrived at the conclusion that for a steel for which 16,000 lbs. per sq. in. would be specified in tension, 12,000—30 l/r should be specified in compression. This means that the unit value of steel in compression has been assumed at three-fourths of that in tension, with a gradual reduction for increasing l/r . No claim is put forward as to the correctness of taking 0.75 instead of 0.7 or 0.8, but from the data at hand this appears to be a safe and reasonable proportion.

Attributing the loss in strength of columns with increasing l/r to lack of homogeneity, local effects of fabrication, and chiefly to imperfect straightness, one is led to the heresy that the radius of gyration of a column exerts no direct influence on its strength, and that the least diameter or width of a column would be quite as good a dimension to use as the imaginary radius of gyration. It sounds old-fashioned to go back to the old ratio of length over least width, but from the study of the Watertown tests it appears to be as scientific as the more pretentious length over radius of gyration. It would certainly relieve many a college student from the trouble of acquiring a physical conception of that mysterious radius.

MR. MANSFIELD MERRIMAN.—What are called compressive stresses in pounds per square inch on the diagram are really not stresses at all, but loads in pounds per square inch. On one side of the column the compressive stress is very much less, and on the other side very much greater than the values given. If diagrams could be drawn so as to actually represent the compressive strength of the material, the curves would assume very different positions from those exhibited and the apparent relation that there exists between compressive strengths and the zone of the elastic limits would entirely disappear. Probably we have not sufficient information to draw such curves; but the point I wish to make is that Mr. Merriman.

Mr. Merriman. those vertical ordinates should not be called compressive strengths, but compressive unit loads.

Mr. Howard. **MR. J. E. HOWARD.**—One feature might be mentioned in this connection with regard to the strengths of the members shown on the diagram, namely, that the stress-strain curve of soft steel not infrequently differs from that of iron. For the former the curve is fairly straight up to the elastic limit and then a jog occurs at which the stress diminishes while the stretching increases, in tests of tension. A corresponding behavior is found under compressive stresses. Not unlikely one of the reasons why the early Phoenix columns of iron showed higher results than the present columns of steel, is due to the very decided yielding of the steel at its elastic limit.

Mr. Talbot. **MR. A. N. TALBOT.**—Of course one cannot go into a technical discussion of the results which have been presented without studying the tests; but I should like to add one word along the line of what has been said concerning the reduction of strength for length of column. In some tests which have been made at the University of Illinois on built-up columns, it has been found that there is a great variation in the amount of compressive deformation over the cross section of a column, amounting to as much as 50 per cent. of the average deformation. This variation differs in different portions of the length of the column, and instead of the change from one distribution to another being at all regular or of there being a graduation from end to middle as might be expected if the ordinary column formula obtained, the transition is quite irregular and somewhat erratic and there is no definite location for the maximum stress. What I wish to bring out is, that in such columns the imperfections of fabrication which we must have with us considerably increase the stresses which are developed in parts of the column; and that even though we may have made too great an allowance by our column formulas for the effect of the element of length, we may thereby have unknowingly allowed for stresses not considered in the analysis on which the column formulas are based.

Mr. Howard. **MR. HOWARD.**—The remarks of Mr. Talbot might apparently be summed up in the statement that better workmanship is needed in columns than commonly given. This drop in the mean strength is occasioned because there was present one column with an ulti-

mate strength only a little over 10,000 lbs. per sq. in. Another one of the same series, kind, and length, showed a compressive strength above 20,000 lbs. per sq. in. Again, in reference to the curve of flat-ended, built I columns, one had an ultimate compressive strength of 13,000 lbs. per sq. in., while a duplicate displayed 27,000 lbs. per sq. in. **Mr. Howard.**

AN INTERESTING DRIVING AXLE FAILURE.

BY M. H. WICKHORST.

The failure of the locomotive driving axle reported below is interesting and somewhat unusual, being a case of an axle failing because of a crack developing internally, and probably also instructive as showing some of the precautions that seem to be necessary in selecting billets from which axles are made. The axle that broke was a crank axle of a balanced compound Atlantic type engine with an original diameter of $9\frac{1}{2}$ ins. The axle was applied at the West Burlington shops, C., B. & Q. R. R., May 25, 1906, and broke while the engine was hauling a passenger train on July 29, 1907. As stated, this was a crank axle and broke in the middle of the journal under the left driving box. Fig. 1 is a photograph of the fractured surface, from which it will be noted that the old crack existed very largely inside of the axle; and it would seem not improbable from the looks of the fracture that the crack first started inside, continuing both outward and inward, although the point of the beginning of the fracture must be said to be uncertain. An analysis of borings taken near the point of fracture at the outside of the axle showed the following results:

Carbon	0.53	per cent.
Phosphorus	0.036	" "
Sulphur	0.011	" "
Manganese	0.43	" "

This analysis is normal for driving-axle steel, although perhaps the carbon is a trifle high. An etching of the section near the point of fracture is shown in Fig. 2. This shows sound material with no indication of piping, but the center portion is seen to consist of very large crystals, some of them $\frac{1}{4}$ to $\frac{3}{8}$ in. long. This would seem to indicate that the billet was rolled from the ingot before the steel had a chance to solidify in the center, leaving the process of crystal formation to go on even after the work of rolling the billet had been finished. The figure shows definitely that later, when the billet was forged into an axle at West Burlington,

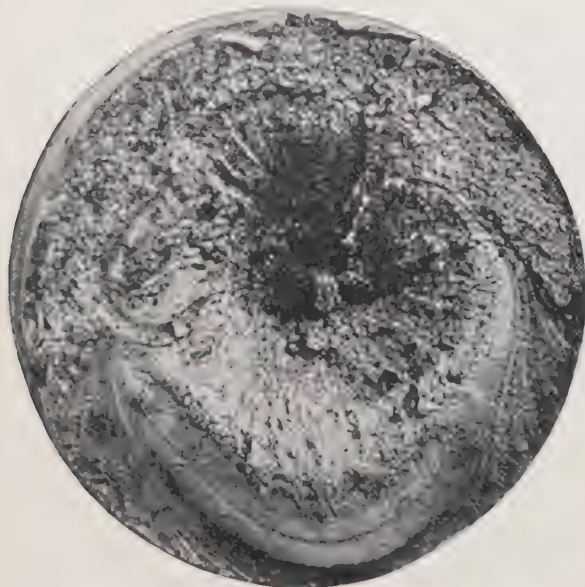


FIG. 1.—Broken Axle from Engine No. 2706.



FIG. 2.—Broken Axle from Engine No. 2706.

the work of forging affected the metal to only a short distance, averaging not much over 1 in. from the outside. We had intended making a full examination of the main portion of the axle, but unfortunately this had been scrapped by the time we finally decided to make a further examination. It seems evident that in forging there was a rectangular core that was but little affected by the hammer, which left severe forging strains, which latter resulted in the internal crack. Fig. 1 shows this crack to have a roughly rectangular shape, indicating the location of the strains.

It has frequently been urged that in buying billets for forgings, it is only important to know that the chemical composition of the material is satisfactory and that the process of forging afterward furnished the necessary work to produce suitable physical properties in the finished forging, and the author has been somewhat partial to this view. This experience, however, seems to show fairly definitely that it is important to have the necessary physical qualities in the billet before the forging is made and it would seem advisable, therefore, to make physical tests of the billets, obtaining the test piece by means of a hollow drill or otherwise.

DISCUSSION.

MR. M. H. WICKHORST.—The question I should like to **Mr. Wickhorst.** have answered is this: If a billet is of coarse crystalline structure, will the process of forging and annealing enable us to make nevertheless a thoroughly good axle?

MR. J. J. SHUMAN.—I believe the answer to that question **Mr. Shuman.** should be in the affirmative, although the result depends on the amount of reduction in forging and the energy of the blow delivered by the hammer. From a superficial study of this paper it appears to me that this axle was either made from too small a bloom or that the forging was done with too small a hammer for the size of the cross section. In either case the center of the bloom would remain about as it was when it left the blooming mill. Mr. Wickhorst proposes to hold the steel manufacturer responsible for the final test of the axle after it has been forged by the railroad company. That procedure strikes me as coming under the "unfair" classification that our President referred to at this meeting. The steel manufacturer should not be held responsible for any metal that receives subsequent heat treatment.

MR. C. L. HUSTON.—I feel that Mr. Wickhorst has put this **Mr. Huston.** question before us in a very fair way. At the same time, I think I should feel like corroborating Mr. Shuman's opinion, especially in regard to the hammer. It is a well-known fact that if a large forging be made with a light hammer, it not only fails to produce density in the central part of the mass but may cause actual rupture, although that is less likely to occur with steel than with iron castings.

I have always believed that in the reduction of a material to its final state, particularly in the case of boiler plate, with which I am especially familiar, most of the work done previous to the fall of the temperature below the point of recalescence does not affect the final condition of the metal, but that the material rearranges itself, especially if reheated, and that only the work done below the point of recalescence is really effective. Possibly this may apply to the present case.

Mr. Wickhorst. MR. WICKHORST.—I stated in my remarks that I recognize that we can spoil a good billet; but I want to know whether we can make a good axle out of a poor billet?

Mr. Shuman. MR. SHUMAN.—Mr. Wickhorst's question seems to imply that a billet which has been finished above the critical point is a poor billet. A billet is not supposed to be a finished product, and the question of temperature does not receive much attention in the blooming mill. In fact, it is hardly to be expected that a bloom the size of that from which this $9\frac{1}{2}$ -in. axle was made could have been finished at a low enough temperature to create a fine structure at the center.

THE EFFECT OF TENSION ON THE SHEARING STRENGTH OF RIVET STEEL.

BY E. L. HANCOCK.

As a part of the general program of tests of materials subjected to combined stresses, the author has investigated the shearing strength of rivet steel when subjected to various tensile stresses. Both structural rivet steel and boiler rivet steel were used in $\frac{1}{2}$ - and $\frac{3}{4}$ -in. sizes. The material was furnished by the Carnegie Steel Company.

Apparatus.—In order to carry out these tests special apparatus

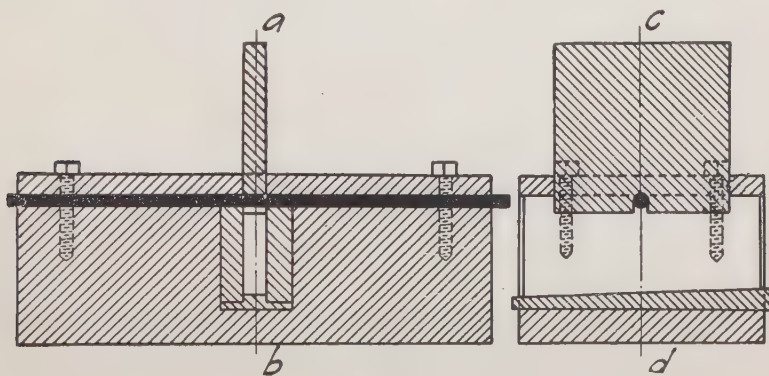


FIG. 1.

were necessary. It was desired to test the steel in double shear with as little consequent bending of the specimen as possible. For this purpose the apparatus shown in Fig. 1 was designed. It rests upon the platform of an ordinary vertical tension-compression testing machine, the moving head bringing pressure to bear upon the shearing plunger at *c*, forcing it downward and shearing the steel rod in double shear. The apparatus used for applying tension is shown in Fig. 2, together with the shearing device just described. It consists of four screws and two cross-heads, *e* and *f*. The head *e* is kept fixed while the head *f* is moved in the

direction of *bb*, by loosening the nuts *bb* and tightening the nuts *cc*. The nuts *cc* act upon four helical springs, one over each screw, in such a way as to transmit the pressure caused by tightening *cc* to the head *f*. With the steel rod inserted and

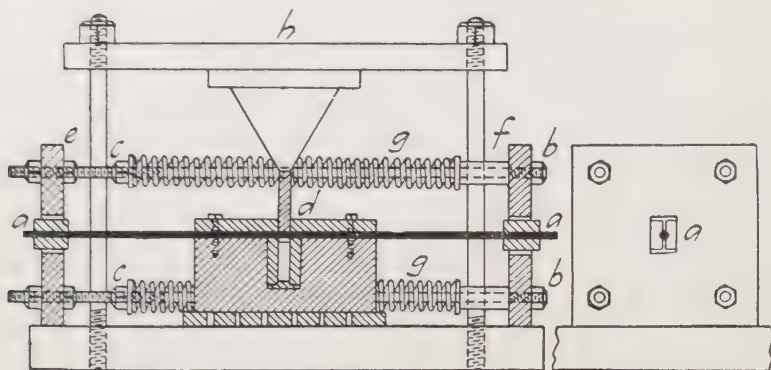


FIG. 2.

the wedges at *aa* driven tight, it is possible by tightening the nuts *cc* to put the test piece under any desired tension. Each spring *g* is accurately calibrated and the amount of compression measured in hundredths of an inch. The combination of the shearing and the tension apparatus just described furnished the means for

TABLE I.—SHEARING STRENGTH OF RIVET STEEL UNDER TENSION.
Pounds per Square Inch.

Specimen.	Diameter, inches.	Tension = $\frac{1}{2}$ Elastic Limit.		Tension = $\frac{3}{4}$ Elastic Limit.		Tension = Elastic Limit.	
		Elastic Limit.	Maximum Strength.	Elastic Limit.	Maximum Strength.	Elastic Limit.	Maximum Strength.
A.	$\frac{1}{2}$	23,000	50,000	23,750	47,300	24,000	39,000
B.	"	25,750	48,000	20,500	43,800	17,800	46,500
C.	"	22,000	49,000	22,750	48,000	20,000	45,800
D.	"	20,000	45,000	21,000	40,200	25,000	46,250
A.	$\frac{3}{4}$	24,300	48,500	14,500	40,600	9,000	43,000
B.	"	22,700	48,000	14,000	41,300	10,250	41,500
C.	"	21,500	46,600	13,500	44,100	10,100	39,000
D.	"	17,250	43,200	18,500	48,000	12,000	39,800
Average. ...		22,000	47,280	18,560	44,160	16,000	42,600

carrying out the desired program of tests. The disposition of this apparatus in the testing machine is shown in Fig. 2. The tests were made in the Laboratory for Testing Materials at Purdue University.

Method of Testing.—The steel was first subjected to tension by means of the four springs g and when the desired tensile stress

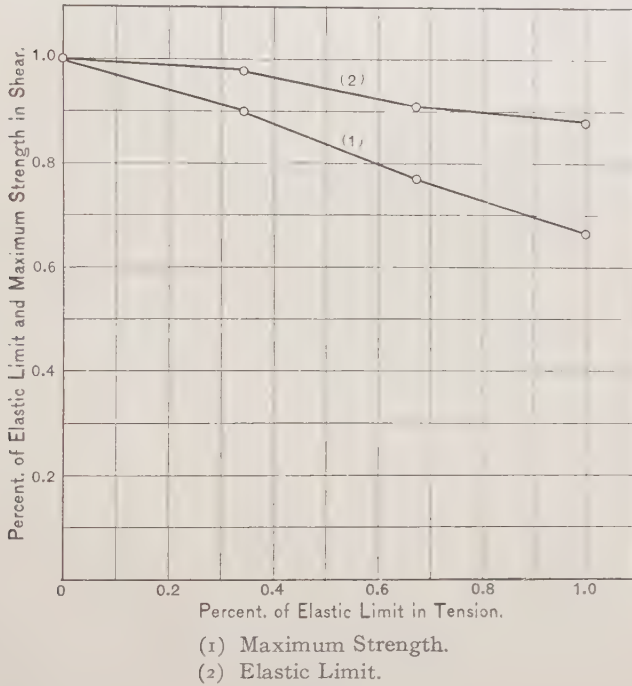


FIG. 3.

was obtained, the shearing test was made by lowering the head h . The shearing tests were made while the steel was under tensile stress equal respectively to one-third, two-thirds, and the full elastic limit in tension. The elastic limit in shear was determined from a load-deformation curve obtained by measuring the movement of the head h for a series of shearing loads, using for this purpose an Olsen compressometer reading to thousandths of an inch.

Results of Tests.—The results of the tests are shown in Table I. The material when tested in tension had an elastic limit of 31,000 lbs. per sq. in., and a maximum strength of 57,600 lbs. per sq. in. The shearing strength at the elastic limit, when no tension was applied, was 23,900 lbs. per sq. in., and at the maximum 48,000 lbs. per sq. in. Each value reported is an average of at least three tests. An examination of the table shows a considerable lowering of both the elastic limit and maximum shearing strength due to the presence of the tensile stress. This effect is shown graphically in Fig. 3. The curves (1) and (2) represent the average of all tests made. The maximum strength is lowered considerably more than the elastic limit.

It is, of course, impossible to determine the amount of tension to which rivets are subjected in actual structures. Tests of riveted joints indicate that there is considerable tension. It seems fair, then, to conclude from the results of these tests as shown by Fig. 3, that this tension should be taken into consideration. This figure shows that if the steel is under tension to three-fourths of its elastic limit, the elastic limit in shear is lowered 10 per cent., and the maximum strength 25 per cent.

THE TESTING OF GALVANIZED AND OTHER ZINC-COATED IRON.

BY W. H. WALKER.

For reasons which are now well understood, one of the most satisfactory, if not the best, methods of protecting iron from corrosion is to cover it with a layer of metallic zinc. This layer of zinc has for many years been placed upon the iron (including hereunder steel) by simply dipping the article, properly cleaned, into a bath of molten zinc. The zinc-covered ware thus produced is called "galvanized iron." This is in itself a misnomer, inasmuch as no galvanic action is utilized in its preparation.

Within the last ten years there has appeared a new kind of zinc-coated iron, wherein the coating of metallic zinc is plated, upon the iron from an aqueous solution of a suitable zinc salt by means of an electric current. Ware of this kind is spoken of as "wet" or "cold galvanized," in contradistinction to the first kind, or "hot galvanized." In still more recent years, a third kind of zinc-coated iron has come into use, made by a rather ingenious process, in which the iron article is heated under pressure in the presence of finely divided metallic zinc and zinc oxide. This ware has been named "Sherardized iron," in honor of the discoverer of the process.

Although the difference in appearance of these three kinds of zinc-coated iron is apparent to the most casual observer, and although a difference in structure incident to the peculiar method of preparation would in each case be expected, no method of testing the value of the three classes of materials other than the now well-known Preece or copper sulphate immersion test has been proposed. As standardized by the American Telegraph and Telephone Company, this test is essentially as follows:

A standard solution of copper sulphate is prepared by agitating a nearly saturated solution of this salt with copper oxide until it is perfectly neutral. It is then diluted to 1.186 specific gravity at 65° F. When a rod of zinc and one of iron are placed in this solution, the metals pass into solution as soluble sulphates, an

equivalent weight of copper being at the same time deposited on the metallic rods. The two metals differ markedly in this respect, however; the copper deposited on the zinc surface is black, spongy, and easily removed; on the iron surface the copper deposit is of a dense bright color.

When this reaction is used in testing galvanized iron, it is assumed that the speed of solution of the zinc is a direct function of the time of immersion, and that by noting the time, that is, the number of one minute immersions, necessary to dissolve the zinc from the iron and in consequence to deposit a film of bright copper thereon, the thickness of the zinc can be estimated. It will be seen that this method measures the thickness of the coating only at its thinnest point, and that the assumption is made that no bright copper will be formed until the iron base is reached. To appreciate the limitations of this test, it is but necessary to note the structure of the three classes of zinc-coated iron mentioned above.

By making a polished oblique section of ordinary hot galvanized iron, and etching with iodine, the structure is seen to consist of three distinct layers. First comes the coating of zinc, the thickness of which varies in accordance with the temperature of the zinc bath and the amount of squeezing or wiping applied to the article before the zinc solidifies. Second, a distinct layer of a zinc-iron alloy which we have termed "alloy B," and which varies in thickness in accordance with the temperature of the zinc bath and the length of time the iron was kept in it. Third, the iron base itself. Between the zinc and alloy B there is generally a very thin, discontinuous layer of second iron alloy, richer in zinc than B, which we call "alloy A," and between the iron and alloy B is a third alloy very rich in iron, called "alloy C." This last alloy is relatively unimportant and will not be further discussed here. Alloy A is always formed in a zinc bath which has been used for some time, and on account of its higher melting point settles to the bottom of the pot as "hard dross." It is interesting to note that while zinc is electro-positive to iron, that is, when electrically connected with iron in water, zinc passes into solution and hydrogen plates out on the iron, both alloys A and B are electro-negative to iron, and by their presence accelerate the solution of the iron, the hydrogen separating out on the

alloy. Both these alloys also, when placed in a neutral copper sulphate solution, precipitate the copper as a bright adherent coating, just as iron does.

The structure of wet galvanized iron is comparatively simple. Although upon some electroplated articles there is evidence of an alloy formation at the junction of the base and the deposited metal, in the case of zinc electroplated iron, an alloy is not easily detected. As the zinc is separated from a solution which need not be contaminated with iron, the layer represents practically pure zinc containing no alloy A.

In the case of Sherardized iron, on the other hand, there is present a relatively complex structure. At the temperature and pressure of the Sherardizing cylinder, the metallic zinc penetrates the iron, forming deep layers of the alloys B and C, but apparently not of A; in place of this well-defined alloy there occur a number of as yet unidentified compounds. Upon the surface there is generally a layer of relatively pure zinc, although frequently the process is carried out to the point where only a deep layer of alloys is formed. When examined under the microscope, this alloy is seen to be covered with deep cracks or fissures, as though the alloy had contracted when forming. It is thus seen that we are here dealing with three very different materials, although essentially the same, namely, zinc-coated iron.

The tests which are to be applied to any structural material must depend upon the point of view from which the material is to be examined. It is the purpose of this paper to treat of zinc-coated iron with regard only to its durability or resistance to corrosion, and without reference to its tensile strength, applicability to fine structure, such as screw threads, etc., or to very large pieces. From this standpoint, a test to be of the greatest value should, if possible, indicate or measure the following factors:

1. The uniformity and thickness of the zinc coating.
2. The continuity of the coating with reference to pin holes.
3. The purity of the zinc.
4. The toughness and ductility of the coating.

I have shown elsewhere that the speed of the corrosion of metals in water or when covered with a film of moisture, is dependent largely upon two factors; first, the escaping tendency

or solution pressure of the metal itself, and second, its ability to set free, or to oxidize, or to otherwise depolarize the hydrogen which is formed as a consequence of the solution of the metal. In the case of the zinc this tendency to dissolve is in itself rather large, but the ability of the zinc to rid itself of the hydrogen is excessively slight. Hence the corrosion of pure zinc in water is very slow. If, however, the zinc be in electrical contact with any material upon which this hydrogen can be liberated or disposed of, the corrosion of the zinc is relatively rapid. The iron-zinc alloy B, and iron itself, are both surfaces on which this depolarizing action can take place, and hence so long as neither the iron nor the alloy be exposed, other things being equal, the zinc coating will not corrode. The importance, therefore, of maintaining a uniform coating of metallic zinc upon the iron can be appreciated. The structure is durable only until the thinnest portion is corroded through. From that time on the action will be greatly accelerated and its rapidity will be measured only by the thickness of the remainder of the coating.

In the copper sulphate test I have already mentioned, it is assumed that when a bright surface of metallic copper closely adherent to the test piece is obtained, the zinc has been dissolved and its thickness thus measured by the time required for the replacement of the zinc by the copper. To determine whether this ratio of the time of immersion required to produce a bright copper surface was in reality a measure of the thickness of the zinc coating, a number of samples of galvanized sheets were obtained and tested according to this method. The weight of zinc per square inch of area was also determined by dissolving the zinc from the sheets without attacking the iron-zinc alloy. This can readily be accomplished by heating the galvanized sample, together with a piece of metallic iron, in boiling caustic soda until the generation of the hydrogen ceases. As might be expected, the ratio between the time of immersion required to show the presence of bright adherent copper and the amount of zinc present per unit area, depends upon the uniformity with which the coating of zinc is spread upon the iron base. In the case of 14 pieces of galvanized sheet iron, for example, the average ratio found was 23, while the greatest variation in either direction was but 2. This test, therefore, so far as indicating the uniformity of the

coating and measuring the thickness of the zinc is concerned, is fairly satisfactory; but alloy B is always indicated as iron, and hence when applied to Sherardized articles, very erroneous and misleading results may be obtained.

It has previously been pointed out that the effect of a free iron surface in contact with zinc is to cause the latter to pass into solution. How small these exposed points can be and still cause this solution, is not definitely known; but their presence cannot be detected by the copper sulphate method on account of the fact that these channels or pin holes down through the zinc to the iron fill up with black, spongy copper and cover up the bright copper spot at the bottom. For this second desideratum of the test, therefore, the copper sulphate method is useless.

While the presence of alloy A in the zinc coating should, and probably does, precipitate copper in this bright form, the particles are so small that they are lost in the mass of black spongy copper. This is true also of other impurities, and hence this copper sulphate method is not available for determining anything regarding the purity of the zinc.

For determining the fourth factor, namely, the toughness or ductility of the coating, the method is again inapplicable on account of the tendency of the spongy copper to cover up the bright copper deposit which indicates cracks extending down through the zinc coating to the alloy or iron underneath.

METHOD FOR DETECTING PIN HOLES AND CRACKS.

The relation between the presence of pin holes in the zinc surface and cracks due to a brittle coating, and the durability of the structure as a whole, has never been studied, largely because no method of detecting these imperfections has been available. The following phenomenon serves as a basis for such a test. If a piece of zinc be placed in a strong solution of caustic soda heated to about 100° C., no action is noticeable. If now the zinc be touched with a piece of iron, hydrogen is liberated in great volume *from the iron*. That is, iron in contact with zinc in hot, strong caustic soda is a seat for the generation of hydrogen. Hence, if a piece of galvanized iron free from pin holes and cracks be so treated, no action is visible; if the iron be exposed, however, to even a minute degree, a stream of fine hydrogen bubbles will

be seen arising from the surface. Small cracks in the zinc coating may be easily detected in the same way.

Ordinary hot galvanized ware is generally very free from imperfections of this kind. Wet galvanized material, on the other hand, is frequently very porous, generating hydrogen at numberless small points over its entire surface. Theoretically, the best electroplated surface is that carrying the greatest weight of zinc per unit area, deposited at the slowest rate. That is, the lower the current density at the kathode in plating, the less porous will be the deposited metal; and the thicker this dense deposit, the better protection will it be. A great many tests on electroplated zinc-coated iron were made, the samples varying in both these particulars. In every case those deposited most rapidly were the most porous, and the results showed that the *time* of plating was more important than the weight of zinc per unit area, although there was a minimum weight below which it was not safe to go.

METHOD FOR MEASURING THE COMBINED EFFECT OF IMPERFECTIONS.

Purity of Zinc.—It has long been known that perfectly pure zinc will not dissolve in acid, and I have elsewhere shown that the rapidity of hydrogen generation from zinc is a function of the presence of an alloy of zinc and iron. Hence the more impure the zinc coating, the more rapid will be its solution in acid. If the test plate be in a horizontal position, since the iron-zinc alloy itself does not dissolve, there will be an accumulation of this material upon the zinc, and the *rate* of hydrogen generation should thus be accelerated.

Pin Holes and Cracks.—The presence of metallic iron in the zinc is also a cause of the rapid generation of hydrogen. Hence the more porous the coating, from whatever cause, the more rapid this evolution of gas will be. As the pin holes get larger, this rate should be also accelerated.

Thickness of Coating.—It is clear that the thinner the coating of zinc, the sooner will the iron base or the alloy B be exposed; and the larger the exposed area, the more rapid the evolution of hydrogen will be, up to a certain maximum.

It is thus seen that all the factors which make for an inferior

coating act in an accumulative way to increase the *rate* at which hydrogen is generated when the zinc surface is exposed to acid. This method has been developed by Mr. Charles L. Campbell, in his thesis for the degree of Bachelor of Science at the Massachusetts Institute of Technology, and was found to give very concordant results. The apparatus employed may take any convenient form, it being but necessary to expose a known area of the zinc coating to a standard acid solution under uniform conditions and to measure the hydrogen generated per minute. In almost every case a sharp maximum is reached giving the resultant of all the different factors which make for rapid dissolution of the zinc. Thus in a series of wet galvanized sheets, those electroplated for 15 minutes reached a maximum of 7 c.c. in 3 minutes; those plated for 30 minutes, a maximum of 14 c.c. in 10 minutes, while those plated for 45 minutes showed a rather low maximum of 6 c.c. in 30 minutes.

In many samples of Sherardized product there are two maxima on the curve showing hydrogen generated per minute. This indicates that there is first an action between the outside zinc coating and the iron-zinc alloy, and later a well defined action between the alloy and the iron.

Service tests with galvanized iron, like similar tests on iron itself, are of necessity very slow at best, and the relation of the above phenomenon to the real durability of the material can be determined only after a number of years. Something can, however, be learned by the study of ware which has already been exposed for a sufficient time to determine its durability. Most of the material available for the purpose was in the form of fence wire, and from a study of these the following conclusions are drawn.

1. *Thickness of Coating.*—In every instance where a very durable fence was found, the coating of zinc proved to be relatively very thick; while on the other hand, the wire fences which showed marked corrosion in from one to two years proved to have almost no zinc on the iron, the zinc color being due to a layer of alloy alone. Thus a barbed wire fence which was made from unwiped galvanized telegraph wire, carried 3.9 per cent. of zinc and after four years shows corrosion only on the barbs, which were made from ordinary closely wiped wire, while another sample which carried

1.4 per cent. of zinc was badly rusted in three years; a third fence in two years' exposure had lost all its coating and was covered with rust.

It is doubtless true that the purity of the iron used in the wire itself plays an important part in determining the ultimate durability of a fence, yet in the opinion of the writer the thickness of the zinc coating calls for more immediate attention. The modern method of close mechanical wiping of the wire as it emerges from the zinc bath, produces too often a wire covered, not with zinc, but with only a thin layer of electro-negative iron-zinc alloy, which affords but little protection to the iron. To produce a wire with a liberal coating of zinc would, of course, cost more both on account of the extra zinc and a somewhat smaller production per machine. But the consumer could well afford, and as it has been frequently proved, is willing to pay more for a fence which will not require the very high cost of renewal within six or at most eight years. While pure iron is a desirable feature in fence wire, what we need most is more zinc on the wire we have.

2. *Purity of Zinc.*—It is a probably necessary consequence of hot galvanizing, that the zinc shall become somewhat contaminated with dissolved iron. It is apparent that this should be kept at a minimum in order that the coating should be of maximum durability.

3. *Flexibility of the Zinc Coating.*—The important objection to placing a thick coating of zinc upon wire used for fencing is that such a coating cracks off when running through the machines. This objection applies, in the first place, only to those wires which are subjected to very sharp bends or turns; and in the second place, it is at least possible that the flexibility of the zinc coating might be increased by mechanical working. It is possible that by passing the zinc-coated wire through dies or under grooved rolls, the crystalline condition of the zinc could be destroyed, and the flexibility and ductility materially increased.

SUMMARY.

1. It has been shown that the copper sulphate immersion test is of value in determining the *uniformity* of coating and the relative thickness of the same in hot and wet galvanized product; but it is worthless in the case of Sherardized products,

and gives no idea of other important factors involved in the durability of the structure;

2. That by immersing a galvanized product in hot, strong caustic soda, the presence of any unprotected iron may be easily detected, however small such area may be;

3. That the weight of the zinc per unit area apart from the zinc-iron alloy may be analytically determined, by dissolving the zinc from the plate through treatment with hot caustic soda while in contact with metallic iron;

4. That theoretically the *rate* at which hydrogen is evolved when the galvanized product is immersed in dilute acid, should indicate its relative durability; that inferior products should reach a maximum in a few minutes compared with a much longer time for better products;

5. That in the very important matter of fencing wire, while the purity of the iron used is of consequence, a more immediate necessity is a heavier coating of zinc on the wire.

6. It is suggested that the flexibility of a zinc-coated wire may possibly be increased by mechanically working the wire in rolls or dies to destroy crystallization in the zinc coating.

DISCUSSION.

Mr. Speller.

MR. F. N. SPELLER.—About a year ago I brought back from the Isthmus of Panama many samples of galvanized sheet roofing and old galvanized pipe. It just occurred to me while listening to Mr. Walker's able paper, that it might be interesting for us to subject some of these samples to his proposed test, and to ascertain how the results will compare with those he found. A good deal of the French pipe and roofing material on the Isthmus is in very good condition after 25 years service. Nearly all of this material was galvanized and painted. Of course a good deal of the metal not so well protected has passed out of existence long ago. I have some samples, however, that are at least 25 years old, and which Mr. Walker is quite welcome to if he would like to apply his test to determine how they will show up in comparison with modern galvanized metal.

My mission at that time was to investigate the question of corrosion in cooperation with some of the Government officers on the Isthmus. It is a splendid field for practical observation along this line. The galvanized pipe of French origin was comparatively thin as regards the body metal according to present day standards, but apparently it had a heavier coating of zinc, and it is evident that those in charge of the painting had good material and were well up in the art. A study of the old French metal paints, which are still efficiently protecting the surfaces to which they were applied 25 years ago, would undoubtedly prove useful to us.

It was quite clear that the galvanizing and paint, which nearly always covered the zinc, was responsible for the long life of the body metal. Some of the body metal proved to be steel, but a larger proportion is wrought iron, and often of inferior quality. However, the quality of the metal underneath was rarely brought to the test in the case of the samples of old roofing which came under my observation, as the protective coatings were usually still doing good service.

Mr. Van Gundy.

MR. C. P. VAN GUNDY.—In relation to this zinc plate from

Panama, I would say that I had a sample of it referred to me about a year and a half ago by a manufacturer in this country, with the remark that this material had been down there 20 or 25 years, and was now in better condition than American plate which had been in service there less than 2 years. He wanted to know the reason for this difference. I had only a very small sample, but I made what tests I could on it. The surface of the plate was rough, and was covered more or less with a coating of oxide, showing that it had been exposed to the weather. Yet, even after this service, I found that it had three times as much zinc on it as the American manufacturers put on their plate, even the best in the market. I had recently a sample of galvanized wire, taken from a fence on Staten Island, which had been standing not over 6 months. The coating was all gone, and the wire was corroded about one-half through. A sample of the same wire which had not been in service at all would not stand one immersion in copper sulphate without showing a lot of copper deposit. I have also seen several carloads of wire fencing within the last month which was no better than this. It had never been in service, but was badly discolored, and would not stand the dipping test. It would seem that a great deal of this trouble might be obviated by coating the wire after the fence has been made, instead of galvanizing it first and then bending it.

THE PRESIDENT.—We have specifications for zinc plates used for car roofing at Altoona. We are requiring four ounces of zinc per square foot. That is as far as we have got. If we had had the information that this paper contains we would have made a different specification. We have a very simple method of determining the total zinc; namely, we cut out a piece 2 ins. square, weigh it carefully, then put it into dilute sulphuric acid and allow it to remain until we are satisfied that all the zinc is dissolved. Then we take out the piece, dry it, clean it, wash it, and weigh it again. We have dissolved unquestionably some of the iron that was part of the plate. We determine the amount of this iron and add it to the weight of the piece of plate that is left. The difference between the first weight and the weight of the sample after it is washed clean plus the iron that we find in the solution, represents the coating. It is a very rapid operation and works very satisfactorily.

Mr. Van Gundy.

The President.

THE PERMANENT MOLD AND ITS EFFECT ON CAST IRON.

BY E. A. CUSTER.

In looking over the work done by this and kindred scientific societies, one cannot fail to be impressed with the wonderful advance that has been made in the knowledge their close scientific research has given us, as well as with the logical means they have pointed out in order that this knowledge may bear practical fruit. Day by day the patient, painstaking work is carried on and unselfishly given to the world at large. It is perhaps natural that the major part of these researches are directed toward steel. The ramifications of this metal are hourly extending, and it is small wonder, in view of what has been accomplished, that the attention of scientific thinkers and investigators has been largely turned to its study. It is at this stage that the writer comes forward with a plea for the humble cast iron.

The work noted in this paper covers a limited field, but enough has been learned to give rise to the thought that in this crude material there lurk potentialities which, when scientifically investigated, may not only enlarge this field but put an entirely different phase on our understanding of cast iron.

Some four years ago, under the stimulus of a disastrous strike, we started on the hunt for the permanent mold, and finally selected cast iron as the material offering the greater number of advantages and the least number of objections. In the course of our investigations it was noticed that certain of the castings, when cool, were soft, while others were hard—in fact, chilled white—the hard castings being in an overwhelming majority. As a remedy we tried various mold coatings of inert materials, but we found that while certain of these coatings gave very good results when applied thickly, yet they retarded the process. In an effort to gain time the coating was neglected, and it was ascertained that when working at good speed, the majority of the castings were soft and could be easily machined. When the coating was entirely discarded and the castings poured and removed from

the mold as soon as they had solidified sufficiently to handle, the total production was soft and no hard castings were produced. After some 14,000 or 15,000 castings had been made under every condition that could be obtained in an ordinary foundry, the following basic facts were established:

1. Molten cast iron does not chill (using the word "chill" to express hard, white crystals) until after it has solidified.
2. Chilling molten iron swiftly to the point of solidification, and then allowing it to cool normally, produces a homogeneous metal.
3. This homogeneous metal possesses certain characteristics that are entirely absent when the same molten iron is poured in sand and allowed to cool in the mold.
4. The chemical constituents of the iron, with the exception of carbon, have little or no effect in modifying these characteristics when gray iron, within ordinary limits, is used.

Inasmuch as all work we have done has been in sections ranging from $\frac{1}{8}$ to 2 ins., it is obvious that the results obtained must be considered in direct comparison with those obtained when these same sections are cast in sand. A casting so low in silicon that it will form white crystals when made in sand, will inevitably form the same white crystals if cast in a permanent mold, even though treated by the process outlined above. This applies principally to thin sections; how far this process can affect thick sections depends entirely upon the ability of the investigator to rob the molten mass of its heat.

In support of the first two propositions, it may be said that molten cast iron is a solution of carbon in iron, with the addition of silicon, phosphorus, sulphur, manganese, and certain impurities—all forming a homogeneous, fluid mass. Now, if this mass could be instantly cooled it would still be homogeneous, the different elements not having time to segregate. Instant cooling is clearly impossible, but we find that swiftly chilling the molten mass produces practically the result desired. The molecular action of forming white hard crystals is only started. When the casting is removed at a bright yellow heat, with the interior still molten, this molecular action—which is nothing more nor less than a continued closing together of the particles—compresses the

molten iron to such an extent that globules of iron exude through the pores and form small excrescences on the surface. This is further shown by the fact that when iron is cast in long bars these bars do not pipe, but the molten iron moves towards the top of the bar, which is partially molten, and forms excrescences at the top. (See Fig. 1.)*

Since the cooling medium, i. e., the iron mold, is removed at the point of solidification, there is no further tendency toward

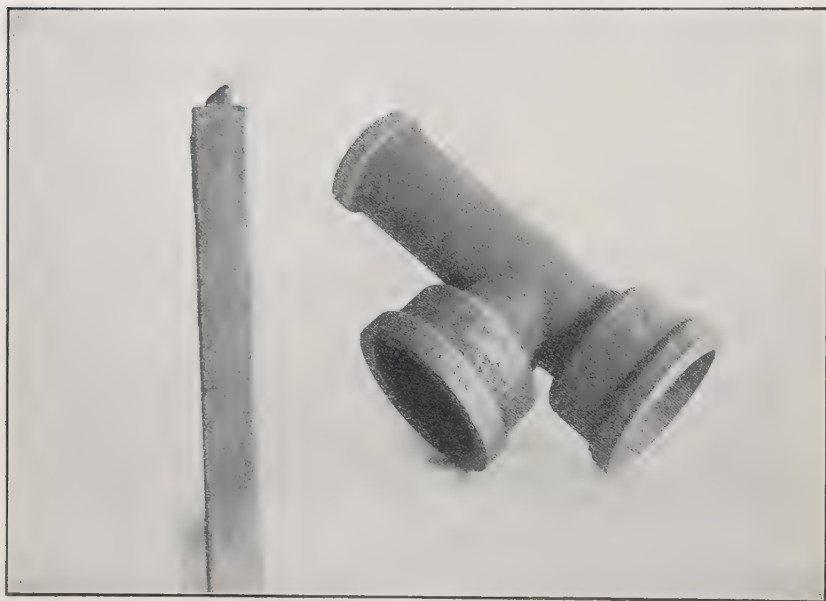


FIG. 1.—Excrescences.

forming larger crystals; furthermore, segregation is completely prevented by reason of the rapidity with which this chilling action is performed. We have tried to reproduce this effect in sand molds, but without success.

Fig. 2 shows a broken section of a casting one side of which was retained in the mold long enough to produce the white crystals; the other side is soft gray iron. This clearly proves the first proposition.

* Acknowledgment is made to the *Iron Trade Review* for the cuts used in this paper.—Ed.

Fig. 3 is a section from another casting which was taken from the mold when the point of solidification was reached and allowed to cool normally.

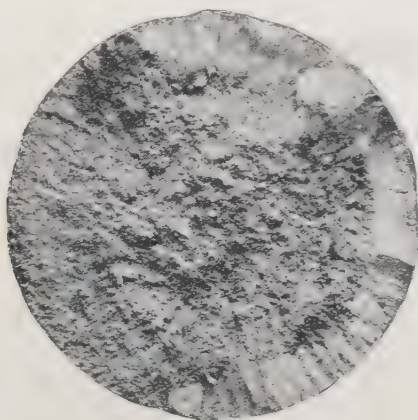


FIG. 2.—Fracture of Partially Chilled Cast Iron.

Fig. 4 shows a section of the same casting taken from the mold at a bright red and quenched in water.



FIG. 3.—Fracture of Soft Cast Iron.

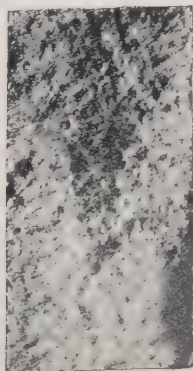


FIG. 4.—Fracture of Hard Cast Iron.

The castings represented in Figs. 2, 3, and 4, were poured from the same ladle of iron. The analysis of this iron is:

Silicon	2.12	per cent.
Sulphur	0.098	" "
Phosphorus	0.70	" "
Manganese	0.38	" "
Total carbon	3.49	" "

No. 2 is useless as a casting, showing white crystals on one side and dark gray on the other.

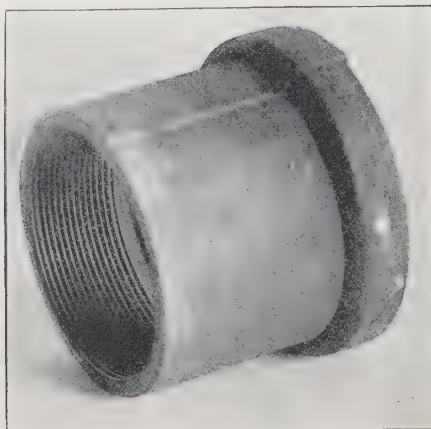


FIG. 5.—The thread in this casting was cut and micrometered. The casting was then heated and quenched in cold water ten times, with a distortion of but 0.002 in.

No. 3 is clean, soft, easily machined, and is as nearly homogeneous as any test we may devise can show. It has a dark gray fracture, machines cleanly, the chips being free from fine dust, and does not show the usual hard scale on the exterior. When heated to a bright red or yellow heat and quenched in cold water, it has a very light gray fracture and is as hard as tempered tool steel. When used as a cutting tool it will outlast any ordinary high carbon steel. If brought in contact with a working dynamo after hardening, it becomes a permanent magnet. It does not possess the disadvantage of increasing in bulk when repeatedly

heated and cooled. This is illustrated by Fig. 5,—a casting that has a distortion of but 0.002 in. after being brought to a bright red heat and quenched in cold water, the operation being repeated ten times. Having once imparted to the iron the properties enumerated above, it is impossible to remove them except by remelting. If No. 3 be held in a bright flame until metal drips from the end, the remaining iron will be unchanged in every particular, with the exception of a slight coating of oxide.

No. 4 shows a light gray fracture, and is an exact duplicate of No. 3 hardened. When heated to the temperature at which it was hardened, and allowed to cool normally, it reverts to the characteristics of No. 3. This heat need not be long continued, the mere heating to the proper temperature being sufficient to accomplish the result.

Figs. 6 and 7 are from the same mold. The analyses follow:

	No. 6.	No. 7.
Silicon	2.94	1.75 per cent.
Sulphur	0.032	0.07 " "
Phosphorus	0.028	1.42 " "
Manganese.....	0.38	0.41 " "
Total carbon	3.08	3.22 " "

These present precisely the same phenomena as Nos. 3 and 4, so far as any tests applied will show.

It would seem, from the analyses of the treated samples, that the peculiar properties observed are entirely independent of whether the silicon, sulphur, or phosphorus is high or low, at least within the limits noted. It is immaterial whether the silicon is 1.75 or 3 per cent., the sulphur, 0.02 or 0.12 per cent., or the phosphorus, 1.50 or 0.03 per cent.; in any event the same practical result is obtained if the procedure outlined is correctly carried out. In no respect have we been able to duplicate these results when the same iron was poured into sand molds of like dimensions.

The logical explanation of this hardening property is that the molecular action, which produces a homogeneous metal by chilling molten iron to the point of solidification, is again the medium of producing the extreme hardness. The first chilling brings the molecules to what might be termed a receptive position. Removing the chilling medium holds this position, and as the temperature falls the molecular position becomes permanent.

If at the receptive point the casting be quenched in cold water, the great unmeasurable force of heat expansion and contraction is brought into play. No one knows how many tons per square inch is exerted when molten iron cools. This force is always greater than the tensile strength of the material under treatment. If, now, the semi-solid iron be subjected to this presumably enormous force exerted through the mold swiftly robbing it of its heat, the molecules are probably crushed together with an enormous pressure, and an extremely dense structure results.

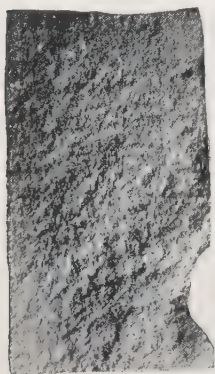


FIG. 6.—Fracture of High-Silicon, Low-Sulphur Cast Iron (Hard).



FIG. 7.—Fracture of Low-Silicon, High-Phosphorus Cast Iron (Hard).

If the casting be quenched in oil, there is no hardening effect; it remains soft. If thrown into boiling water, it cracks into pieces.

Fig. 8 shows the fracture of an ordinary forged and hardened steel file placed alongside of hardened cast iron, in Fig. 4. The analyses follow:

	File.	Cast Iron.
Silicon	0.19	2.12 per cent.
Sulphur	0.022	0.098 " "
Phosphorus	0.019	0.70 " "
Manganese	0.25	0.38 " "
Total carbon	1.28	3.49 " "

This photograph shows very clearly the coarse grain of the cast iron and the metal flow of the steel file, yet the cast iron is the harder metal.

Fig. 9 gives a very good idea of the difference between casting in sand and in a permanent mold. This fracture is of the same iron that was used for Nos. 2, 3, and 4, and was cast in a green sand mold and allowed to cool normally.

Figs. 10, 13, and 21 are microphotographs of Figs. 3, 4, and 9, and present a very fair field for discussion. They were etched with picric acid, and each given a magnification of 104 diameters. The fracture photographs have a magnification of 2.5 diameters.

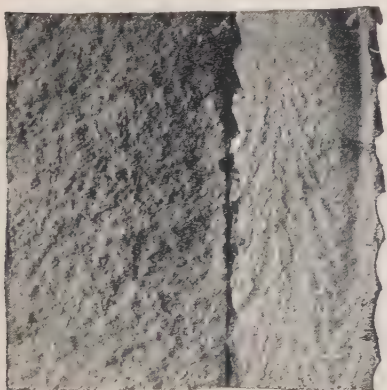


FIG. 8.—Fracture of File and of Hardened Cast Iron.



FIG. 9.—Fracture of Ordinary Cast Iron.

In this work carbon plays a large part, although it does not seem to have the same effect as when iron is cast in sand. A few notes on this phase may be interesting.

Since all the carbon in molten iron is in solution, and exists in the combined form, then, if molten iron be instantly cooled to 1000° F., all the carbon will be held in the combined form—there will be no free carbon. If, however, it be instantly cooled to the point at which the iron sets, and then allowed to cool normally, the carbon will be in the combined form at the time of setting, but will change to the free form as the cooling progresses. This formation of free carbon is very rapid; the major portion present

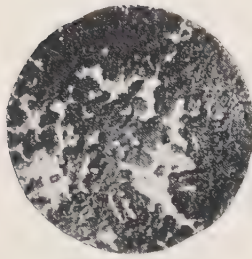


FIG. 10. $\times 104$.

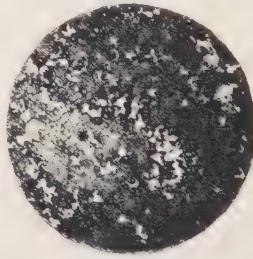


FIG. 11. $\times 30$.

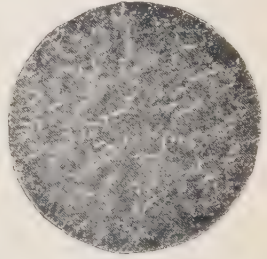


FIG. 12. $\times 30$.
(Oblique light.)

Iron Cast in Permanent Mold (Soft, same as Fig. 3).

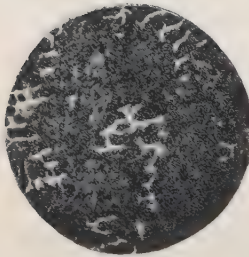


FIG. 13. $\times 104$.

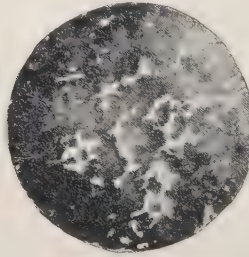


FIG. 14. $\times 104$.

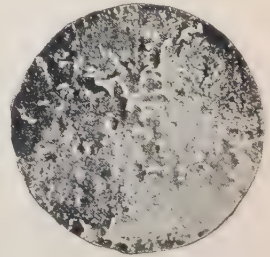


FIG. 15. $\times 104$.

Iron Cast in Permanent Mold (Hard, same as Fig. 4).

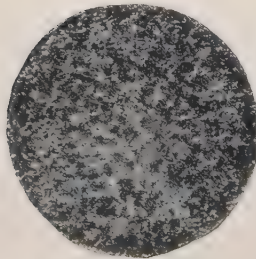


FIG. 16. $\times 30$.
(Oblique light. Same as Fig. 4.)

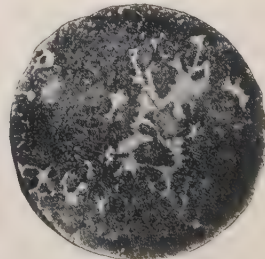


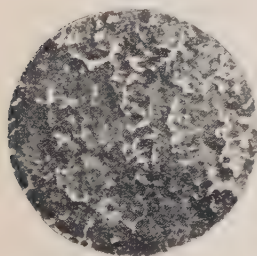
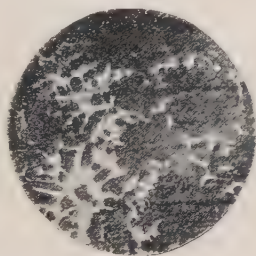
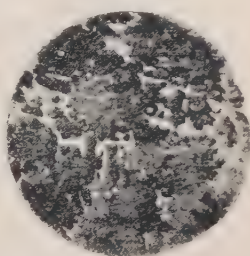
FIG. 17. $\times 104$.
(Same as Fig. 6.)

Iron Cast in Permanent Mold (Hard).

in the casting is formed within a few seconds after it is taken from the mold. The analyses below give a very fair idea of this action, the pieces in question being 6 by $1\frac{1}{4}$ by $\frac{1}{2}$ ins:

	Combined Carbon, per cent.	Free Carbon, per cent.	Silicon, per cent.
Cast in sand and cooled normally	0.21	2.93	2.61
Taken from permanent mold at bright yellow and quenched	1.50	1.52	2.61
Taken from permanent mold at bright red and quenched	0.49	2.61	2.61

It will be seen from this that two-thirds of the combined carbon has been changed in the few seconds required to cool

FIG. 18. $\times 104$.FIG. 19. $\times 104$.FIG. 20. $\times 104$.

Iron Cast in Permanent Mold (Hard, same as Fig. 7).

from bright yellow to bright red. The free carbon in all these castings is not in the form of graphitic carbon, as we usually see it in ordinary cast iron, but partakes more of the character of annealing carbon, as exhibited in a malleable casting.

Here we have an iron containing 2.61 per cent. of silicon and 2.50 per cent. of free carbon, that possesses the property of taking a temper equal to tool steel, and this without the least indication of what is generally termed "chill."

At this writing, the tensile strength is under investigation. The scope of this research is very large, and many elements must be taken into consideration. Our results so far indicate that cast iron, when chilled in a permanent mold to the point of setting and then cooled normally, is greatly increased in tensile strength, and that this strength does not materially vary within the chemical

range of ordinary foundry iron. The thickness of the section and the initial heat of the casting have the greatest influence in determining the ultimate strength, and these variations call for an extended consideration.

Heretofore cast iron has had a rather poor reputation, being generally unstable and yielding reluctantly to any treatment that would tend to improve the quality. The permanent mold has rendered valuable service in demonstrating that the simplest of

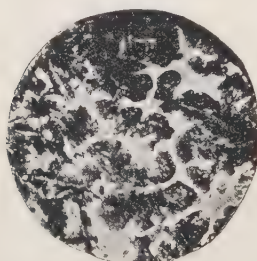


FIG. 21. $\times 104$.
Same Iron as Fig. 3, but Cast
in Sand. See Fig. 9.

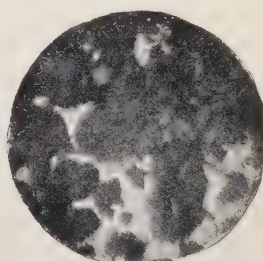


FIG. 22. $\times 104$.
Fragment from Large
Casting.

simple heat treatments endows it with characteristics which entitle it to a very large portion of the consideration that has hitherto been enjoyed by wrought iron and steel. One hardly dare say that the ultimate possibilities of this metal have been reached, nor can it be considered in the light of an unstable and refractory medium. On the contrary, it answers readily and surely to the proper treatment. The field is wide and gives promise of much that would place cast iron on a far higher plane than it occupies to-day.

I wish to acknowledge the keen interest and self-sacrificing help of Robert A. Pitman, without whose devoted work much that has been accomplished would have been lost.

DISCUSSION.

MR. H. M. HOWE.—I am very much interested in this Mr. Howe.
paper. I think that the subject is one of very great promise. The metallurgy of cast iron is much more complicated than that of steel and will probably be slower in developing, but it has a great future.

I do not think it is necessary to regard the phenomena as complicated in this case. I think that they admit of very simple explanations. It seems to me that in these castings we have something which is intermediate between gray cast iron and malleable cast iron annealed in sand or lime, or some other substance which does not remove any of the carbon. When cast iron solidifies rapidly, or in case of low silicon iron even when it solidifies rather slowly, it forms at first austenite and cementite, the components of hot solid white cast iron. But this cementite tends very strongly to change into a mixture of graphite and austenite, the components of hot solid gray cast iron. If the solidification and cooling are slow there is time for this change to occur, and the metal actually becomes a mixture of graphite and austenite. In further cooling the graphite remains, and the austenite changes into the usual mixture of pearlite and either excess ferrite or excess cementite as in our usual gray irons. But for simplicity we may here lose sight of this change of austenite, and concentrate our attention on the graphite, which gives us the key to the whole matter.

If foundry iron, i. e., iron with a fair amount of silicon, solidifies in a sand mold, the cooling is slow enough to allow the graphite, the formation of which is stimulated by the silicon, to form while the metal is still pasty, and the softness of the metal in which the graphite forms enables it to collect in relatively large flakes. Hence the relatively large flakes of graphite seen in the fracture of gray iron castings. If, as in making malleable castings, you cast it with but little silicon, so that you make a white cast iron to start with, then anneal it and make malleable cast iron, graphite forms as before, but because the metal in which it forms is relatively

Mr. Howe. cool and hence rigid, this graphite forms in fine powder instead of in large flakes. Fine powder breaks up the continuity of the whole mass less harmfully than large flakes do. Hence the strength of malleable iron; for that reason and no other.

In this particular case of permanent-mold castings you have something approaching malleable cast iron. The iron is cast and the cooling proceeds at such an intermediate rate as allows the formation of the graphite, but yet the rate is not so slow that the graphite will form large flakes, and you have the graphite forming very minute flakes, approaching the condition that you have in the case of malleable cast iron. Hence the strength of these castings. There is a very close resemblance.

As to the hardening of such cast iron, of course it will harden. That was to be foreseen and while it is interesting, should not cause the least surprise.

In the red-hot metal you would have graphite of course, but together with it you have much austenite. Sudden cooling hardens the austenite, exactly as it hardens any steel. The case is comparable with that of the cast iron tools which were used at Altoona with very great success. They did the work of a hardened steel tool, and did it in a very economical way. So I do not think that we have any reason to believe that any remarkable or paradoxical phenomena are present here. I think we have the same old phenomena produced in a way that we are surprised we did not think of before. Nevertheless the process is likely to have an important future, but I do not see any reason to revise our former theory or to consider these new phenomena as paradoxical.

Mr. Custer. **MR. E. A. CUSTER.**—We have made some tests with this iron by making some white chilled castings and then quenching them in water. The metal simply crumbles on application to a grindstone. I think the tests of chills made both ways show that iron taken from the mold at a bright red heat and quenched in water has about two and a half times the resisting power of the same iron when it is chilled in white crystals.

Mr. Skinner. **MR. C. E. SKINNER.**—I should like to ask the author if he can tell us something about the shrinkage observed in castings made in a permanent mold as compared with castings made in a sand mold?

Mr. Custer. **MR. CUSTER.**—It is about the same.

THE PRESIDENT.—I should like to ask concerning the manipulation as affecting the output of this and the sand mold? The President.

MR. CUSTER.—We make plowpoints in those molds at the rate of one every 10 seconds. We make soil pipe at the rate of one every 15 seconds. We can make three brake shoes a minute, and we make them without any molders and without any sand. We make our permanent cores of the same iron as the molds, and we simply pull the cores out at the proper time. If the cores are gotten out in time the iron will be soft. Failure to get the core out in time results not only in hard iron but also in cracked castings. Mr. Custer.

THE STRUCTURAL MATERIALS TESTING LABORATORIES,
UNITED STATES GEOLOGICAL SURVEY:
PROGRESS DURING THE YEAR ENDING
JUNE 30, 1909.

BY RICHARD L. HUMPHREY.

Nearly five years have elapsed since the establishment in the cement exhibit of the Louisiana Purchase Exposition, Forest Park, St. Louis, Missouri, of a laboratory for testing cement and investigating mortars and concretes, and four years have elapsed since the continuance of these and other investigations of structural materials under the direction of the U. S. Geological Survey. During this latter period the work of the laboratories has broadened as rapidly as the conditions would permit, until the work covers many lines of investigations. By reason of the temporary location in Forest Park, investigations were limited to those which could be completed during the time allotted for operation in St. Louis, which was extended far beyond that originally contemplated through the generosity and consent of the officials of the city of St. Louis and the officers of the Louisiana Purchase Exposition Company. The final restoration of Forest Park necessitated the immediate removal of the laboratories to the only Government buildings available, namely, those belonging to the Quartermaster General, U. S. Army, on the Arsenal Grounds, Fortieth and Butler Streets, Pittsburg, Pa., which was made possible through the courtesy of the Secretary of War. Before this removal was effected, all tests were completed with the exception of those of the smaller test pieces that could be transported without injury.

The work in these laboratories is carried on under Government appropriations for the investigation of materials belonging to or intended for the use of the Government, and in the program for the expenditure of the money appropriated for each fiscal year, precedence has been given to the requests of the various departments of the Government for information or data relating

to the suitability and availability of materials to meet special problems arising in connection with the construction of public works.

Consideration has also been given to the continuance of the investigations in accordance with the program approved by chiefs of the various Bureaus of the Government engaged in construction work. This has involved the examination of several thousand samples of various materials, necessitating more than 150,000 tests and determinations, the results of many of which have already been collated and published in a number of bulletins.

Since the inauguration of the tests in St. Louis under the direction of the U. S. Geological Survey, a report has been presented at each annual meeting of this Society, outlining the work accomplished and noting special items of interest for the period elapsed since the previous report. When this work was started, a large amount of time was necessarily required to develop the organization of a force of skilled assistants and the installation of the apparatus and equipment necessary to carry on the investigations contemplated. To-day these laboratories possess the apparatus and equipment necessary for investigations of all kinds of structural materials and in addition a force of trained assistants capable of efficiently executing the work. During the past year more than 18,000 tests and investigations have been made, as well as about 700 chemical analyses involving nearly 6,000 determinations.

Investigation of Clay Products.—With the installation of the laboratories in Pittsburg, there has been inaugurated an investigation of clay products under the able direction of Mr. Albert V. Bleining, Ceramic Chemist, assisted by Mr. H. E. Ashley, Assistant Ceramic Chemist. By reason of the necessity for adapting the existing buildings, securing and installing the necessary equipment, and effecting a proper organization for the prosecution of the work, no important experimental results have as yet been obtained.

These investigations involve the examination of the clays belonging to the United States with the view to furnishing the various departments of the Government with data regarding the strength, durability, fire-resistive properties, and the physical characteristics of the resulting clay products in order to determine

their suitability for the various public works. These products, among the oldest of our building materials, have not received the same careful investigation as other and newer materials, with the result that there is important work to be done in supplying the much needed data concerning their physical and chemical properties. The program of investigations as at present outlined consists of (a) the fundamental properties of the various clays belonging to the United States; (b) the preparation of specifications for clay products such as fire brick, architectural tile, brick, etc., used in the construction of Government work; (c) the development of methods for classifying clays; (d) a study of the property of clays when burned in various structural forms, bricks, tiles, etc. In this investigation a new departure has been made in the study through the use of a cylinder of the burned clay on which to make determinations of its elastic properties. (e) Investigations of the load-carrying capacity of fire brick at high temperatures obtained through the medium of an electric furnace, have also been completed.

Investigation of Lime.—In connection with and supplemental to the above investigations, there has also been inaugurated in the Pittsburg laboratories an investigation of the properties of lime. While the preliminary program covers only the fundamental properties relating to the lime and methods of manufacture, the investigations will be extended as rapidly as the conditions will permit.

Investigation of Building Stones.—At the request of the Supervising Architect an extensive investigation of the building stones of this country has been inaugurated, involving a systematic survey covering not only the geological and economical features but also the various physical properties such as strength, durability, and resistance to fire, weather and other destructive agencies. In connection with the tests of strength and other physical properties, large blocks of stone are being shipped to the Pittsburg laboratories and sawed into test pieces of various sizes. For the determination of strength, the test pieces will be 12 ins. square and 24 ins. high. These tests will be paralleled with a series of tests of 2-in. prisms 4 ins. high and also 2-in. cubes, in order to afford a comparison of the value of the large and small test pieces. Tests are also being made in a specially constructed

furnace as to the fire-resistive properties of these stones tested under conditions which will develop the quality of stone quarried in relation to the rift, grain and hardway. The determination of the compressive strength of the large blocks of stone is made possible through the installation of the 10,000,000-lb. testing machine. It is expected that valuable data will be obtained indicating the effect of various structural weaknesses in the stone which it would be impossible to develop in a smaller test piece. In addition, artificial weathering tests will be made in an apparatus especially constructed for the purpose. These investigations are under the supervision of Mr. E. F. Burchard, Assistant Geologist.

Washington Laboratory.—In connection with the investigations of materials of construction for the Supervising Architect, there is being maintained under the direction of Mr. S. S. Voorhees, Engineer of Tests, a special laboratory, which is accomplishing valuable results in determining the suitability of large quantities of materials intended for use in the construction of the Federal buildings. The laboratory is located in Washington in order that the time required in making these tests may be reduced to a minimum.

Fire-Resistive Tests.—There are in progress comprehensive investigations of the rate of heat conductivity and other fire-resistive qualities of the various building materials, of the amount of insulation necessary for the protection of structural materials, and of the comparative value of various types of fireproof construction and fire-protective devices. Tests have been made on panels built of blocks of concrete 6 ft. long and having steel rods embedded at different depths from the surface subjected to the heat treatment. Tests were also made on panels of various types of building blocks, several kinds of building stone, and clay bricks. These investigations are under the charge of Mr. E. B. Tolsted, Junior Engineer.

Chemical Laboratory.—All the chemical analyses and investigations required in connection with the investigations of structural materials by the various sections, have been made in the chemical laboratories at Pittsburg under the supervision of Mr. Phaon H. Bates, Chemist-in-charge.

Special Tests, Government Bureaus.—The dismantlement of the laboratory at St. Louis and its installation at Pittsburg has

necessarily resulted in considerable curtailment of the test work that could otherwise have been accomplished during the year. This work has been further limited by the fact that the tests for the Government departments had to be made even while the plant was being transferred, making the continuance of investigative work for that time out of the question. The investigations during the past year were distributed as follows:

Isthmian Canal Commission.—In order to determine the value for use in concrete of some of the sand and stone found at or near the canal site, very complete tests were undertaken. The ultimate strength in compression, the elastic properties, density, and permeability, were determined for concrete in which the amount of cement and the proportions of sand to aggregate were the variables.

Corrosion tests on wire screening which were commenced during the preceding year were completed. Tests were made on screens containing wire of different compositions, in order to determine that best able to withstand the Isthmian climatic conditions.

Acceptance tests of wire rope cables of different qualities of steel and types of manufacture, and varying in size from $\frac{3}{8}$ in. up to $1\frac{1}{2}$ ins., were made. The tests involved the determination of the elongation and reduction in diameter under load, as well as the ultimate strength. Chemical tests of the rope preservative were sometimes made.

Similar tests were also made on Manila rope from $\frac{3}{8}$ in. up to $3\frac{1}{2}$ ins. diameter. In some instances tests to determine the kind of fiber used were also made.

Tests were made on six samples of material in order to determine its value as a Puzzolan cement. The material was used as it occurred in nature, and also mixed in various proportions with Portland cement and hydrated lime.

United States Reclamation Service.—The investigation of the effect of alkaline salts on concrete construction was continued from the preceding year. This involved the chemical analysis of a large number of samples of concrete, mortar, incrustations on concrete, soil, and water, collected on a number of Reclamation projects in the West. A number of hollow mortar cylinders were filled with various alkaline salt mixtures, and the action of the solution as it percolated through the walls of the cylinders was noted

and an analysis of the effluent made. These tests are still being continued.

Tests have also been made of a number of sands and gravels to determine their suitability for mortars and concretes.

Compression tests have been made on standard 8- by 16-in. concrete cylinders stored in air, in fresh water, and in alkaline water on several of the Reclamation projects.

Permeability and damp-proofing tests have been made of commercial waterproofing compounds.

In addition to the above, routine tests of the compressive strength of concrete cubes and chemical analyses of cements have been made.

Supervising Architect of the Treasury Department.—A series of overhanging concrete slabs reinforced with various types of reinforcement were tested to destruction under uniform water load. Deflections were determined for each foot of the span and overhang.

Tension tests of reinforcing steel have also been made.

Investigations into the physical and chemical properties of marble from several parts of the United States have been conducted at various times.

Department of the Constructing Quartermaster, U. S. Army.—Several investigations as to the value of sands from different parts of the United States for use in concrete have been completed, as well as several series of tests on marble.

Navy Department.—Tests of slate have been made.

The above tests and investigations for the various Government departments have been under the charge of Mr. Louis H. Losse, Assistant Engineer.

Concrete and Reinforced Concrete.—The survey of the constituent materials of concrete was inaugurated about two years ago for the purpose of determining the quality of concrete made with sand, gravel, and crushed stone from various parts of the United States. During the present year tests were made on crushed stone from Joliet, Ill., and Milican, Texas; on gravel from Colfax and Baton Rouge, La., and Fort Worth, Texas; and on sand from Topeka, Wichita, and Leavenworth, Kansas.

During the preceding year a series of reinforced concrete beams was prepared with the cooperation of several St. Louis contractors, in order to compare beams made up under laboratory

conditions with those approximating actual practice. A 1:3:6 concrete was used in order to develop a compression failure and thus judge of the relative quality of the concrete. During the present year a portion of this series was repeated using a 1:2:4 concrete.

A preliminary series of tests on plain mortar and concrete columns of various proportions and ages was started and has been completed.

Static load tests were started on concrete beams reinforced with rods of different diameters. Two aggregates, gravel and limestone, were used. While the same percentage of steel was used in all beams, those containing the larger steel were known to fail at maximum load due to the slipping of the rods, while those containing the smaller rods failed from the stress in the steel exceeding the yield point. These tests are still under way.

Atlantic City Laboratory.—The installation of this laboratory, which has for its object the investigation of the effect of sea water on cement and other structural materials, was not commenced until December, 1908, and in view of the little work of a similar nature that has been done heretofore, the tests during the early part of 1909 were mostly preliminary in character.

A large number of samples of sea water taken at different times were first analyzed in order to determine the uniformity that could reasonably be expected. Considerable time was spent in experiments to discover the most satisfactory methods of determining the effect of sea water on cement, and it was not until May that a method was devised which it is thought will be satisfactory. A small quantity of a large number of cements were then agitated with sea water and the water is being analyzed at intervals.

Several kinds of concrete were made up into the standard 8- by 16-in. compression cylinders and, after storage for different periods in sea water, are being tested in compression. A comparison of the strength of briquettes stored in sea water and in fresh water is also being made.

This work is under the charge of Mr. Rudolph J. Wig, Assistant Engineer.

Northampton Laboratory.—This laboratory was installed at the works of the Atlas Portland Cement Company in the late fall of 1908 and test work started during November. The work

of the laboratory is confined entirely to the routine tests of cement for the Isthmian Canal Commission. The method of inspection is such that the cement is under control in bins, sealed for a period of at least 28 days during the process of testing, and is not accepted for shipment until it has satisfactorily met the requirements. From the beginning of operations in November to June 30 of the present year, 1,267 samples, representing 121,000 barrels of cement, have been tested.

Mr. William A. Campbell, Assistant Engineer, was in charge until forced by ill health to apply for a leave of absence. He has been succeeded by Mr. A. D. Gates, Junior Engineer.

New Equipment.—The most notable new equipment during the year is the vertical 10,000,000-lb. testing machine capable of testing in compression test pieces 65 ft. in length. This was primarily acquired for the purpose of testing large blocks of stone made necessary by the study of the building stones of the United States and of large masonry columns of brick and reinforced concrete with a view to securing much-needed information as to their carrying capacity, but will also be available for testing large columns and struts of other material. The machine consists of a large hydraulic press with one adjustable head and a weighing system for recording the loads developed in it by means of a triple plunger pump operated by a variable-speed electric motor. The maximum clearance between the heads, which are 6 ft. square, is 65 ft. and the clearance between the main screws is a trifle over 6 ft.

Conclusion.—The investigations by the Government of the fundamental properties of building materials belonging to and for the use of the Government, which admit of the framing of more rigid specifications through the establishment of reliable data concerning various chemical and physical properties and permissible working stresses, are of inestimable value in enabling Government officials to make more intelligent and economical use of the various available materials in the construction of Federal buildings. The investigation of the fire-resistive properties of building materials will undoubtedly lead to the construction of buildings of a higher fire-resistive type not only by the Government but by the country in general, and this will undoubtedly tend to reduce our present enormous losses from fire and to conserve our building materials.

A SUGGESTION AS TO A COMMERCIAL USE TO BE MADE OF CEMENT TESTING.

BY RICHARD K. MEADE.

The tests applied at the present time to Portland cement are designed to serve two purposes; first, to insure the permanency of the construction in which the cement is used, and second, to give it the proper strength. So far these tests have been applied largely with one object in view; namely, that of securing a cement which could be relied upon to impart a fair degree of strength to concrete in which it might be used and to give a mortar constant in volume. It seems that at the present time we have reached a point when we can go farther than this, and it is the intention of the present paper to suggest that the fineness of Portland cement, or its tensile strength when tested with sand, or both, be used as an actual indication of its commercial value.

Specifications are more and more beginning to recognize the fact that it is not only a case of securing a material which is free from defects, but also of securing a material which will be the best possible for use in the construction, or certainly the best possible which may be obtained within the limits of the figure which it is designed that the completed work shall cost. The specifications now drawn up by the United States government experts for the purchase of coal do not merely define a certain maximum limit for sulphur and ash, and a certain minimum number of British thermal units which the coal shall possess, but go further and purchase the coal upon a sliding scale by means of which the dealer gets some of the advantages of extra quality. Why can not a similar sliding scale based on the cementing value be applied to cement?

Of two cements, both of which pass satisfactorily the tests for soundness, time of set, fineness, etc., the one which has a tensile strength 50 per cent. greater than the other, when tested with sand, is certainly very much the more valuable of the two for constructive purposes, and the fact that the latter passes the standard requirements and can be bought slightly cheaper is no reason why it should be employed in preference to the former.

Manufacturers should be encouraged in every way to make the best possible product which their works can turn out economically. Nothing has served to stimulate this better than wisely drawn specifications. Contractors should also be required to use, *not* the cheapest material which passes specifications laid down for them by the engineer, but the best material which they can put in at a fair profit on the job. It seems, therefore, that there should be some bonus which would encourage the contractor to use the best material which he can obtain, rather than the poorest which he could possibly use and still fill the legal requirements of his contract.

A cement, A, which when tested with sand in the proportion of 1 to 3 is found to have 50 per cent. greater strength than another cement, B, tested under similar conditions and with an equal amount of sand, will be found to have fully as great strength tested 1 to 4 as the second cement, B, tested 1 to 3. This applies not only to small tensile test pieces but also to cubes made of concrete. It is therefore perfectly safe to use less of the strong cement than of the weak one and still have as good concrete as can be made by the weak cement. In the middle West, engineers are beginning to write specifications which do more than merely insure against defects in the cement, and which place a premium upon the best which can be used. As an example of such a set of specifications, the following paragraph taken from the specifications for a concrete viaduct to be built on Lydia Avenue, Kansas City, Mo., for the Chicago, Missouri, and Pacific Railway Company, and the Metropolitan Street Railway Company, by Mr. Kenneth Hartley, C. E., may be cited:

In case the cement used in this work should be ground to a fineness exceeding the standard specifications by more than 2 per cent. through the 200-mesh screen, the contractor may reduce the amount of cement per cubic yard of the concrete by 3 per cent. of the above quantities for each decrease of 2 per cent. in the residue retained on the 200-mesh sieve.

In other words, if the cement is ground so fine that 85 per cent. of it shall pass the 200-mesh sieve, the contractor need only use 85 per cent. of the quantity of cement in his concrete which he would otherwise have to employ. It is estimated that provided he could secure a finely ground cement for the same figure

as the other, there would be a saving of 15 per cent. of the cement in the use of the former, or in the specific case of this viaduct a saving of \$500. Nor is the saving entirely on the side of the contractor, since concrete made with 75 per cent. as much cement, 85 per cent. of which passes the No. 200 test sieve, is as strong as concrete made with the full amount of cement only 75 per cent. of which passes this sieve. As the contractor is to use 85 per cent. as much of this cement, the engineer really gains. Furthermore, when a cement has low strength its composition is faulty, it is underburned, adulterated or coarsely ground, any one of which is certainly not to be recommended in cement. Often large government and municipal works, where only the best cement should be used, employ a very poor product, comparatively speaking, simply because the contractor uses the cheapest cement he can procure which will pass the specifications of the engineer.

The Kansas City specifications are along the line of all recent investigations made upon the value of finely ground cement, and indeed the quantity of cement might be reduced very much more than these specifications allow. Our own experiments have demonstrated that this reduction may amount to 2 per cent. of the cement for each decrease of 1 per cent. in the residue retained on the 200-mesh sieve.

DISCUSSION.

MR. R. W. LESLEY.—We have before us our old friend “Fine Grinding.” There is no doubt that the paper opens a very wide field for discussion. As to the thought advanced by the author of giving a premium for fine grinding, I do not think there is anything new in this because away back in the time of the Tombigbee River improvement and other river improvements in several of the Southern states, the safeguard to which the writer refers was required. Specifications expressly provided that the man who could meet the sand mortar requirement with a minimum amount of cement, should get more per barrel for his cement than the man whose cement would carry less sand. All this is referred to in a number of old Government specifications. Why the practice was abandoned I do not know. My own recollection is that it did not work out so well down there in actual practice as it did in the testing laboratory. At any rate it has not been attempted in late years. Mr. Lesley.

MR. R. L. HUMPHREY.—It seems to me there are a great many more important things to be considered in the use of cement than the question of premium for fine grinding. There is a craze regarding fine grinding at the present time. When we consider that the cement forms a very small percentage of the mass of concrete, and when we consider further the sand which goes into the concrete, and above all, the conditions under which the materials are mixed, it seems to me it would be an unwise thing to begin dodging specifications which are serving admirably by putting a premium on finer grinding. To cut down the quantity of cement in a mixture by a certain fractional amount would seem to me an unwarranted proceeding, even if it is demonstrated under laboratory conditions that the finer cement produces a stronger mixture. Mr. Humphrey.

MR. LESLEY.—My own experience in this connection may be said to go back to history. There was a time when the higher the tensile strength we could guarantee the customer the better he was satisfied. It did not make any difference what the other

Mr. Lesley. qualities were so long as he obtained the highest tensile strength. But lately a new idea has entered, namely, that the cheaper you can give the cement to the customer the better it is for all parties. It is not an engineering question, but rather a financial one.

As indicating that we have reached the limit of giving cement away, I received to-day a circular from a lime manufacturer who is getting \$2.00 more per ton at the kiln for his bulk lime than the Portland cement manufacturer for his highly finished product. No one who is familiar with the difference in the cost of production between bulk lime and Portland cement would fail to realize what it means to sell cement at the prices that are now prevailing. Having, however, reached the limit of selling this finely pulverized material which has been clinkered at temperatures almost equal to those of the iron furnace, it seems but proper that at the present time the question should come up of how much finer we can grind it. In a paper read some years ago, I think by Mr. Henry S. Spackman, dealing with the matter of fine grinding, the experiments cited at that time showed that there are a great many things to be considered beyond the mere grinding of the cement. It was found, for instance, that the shape, size and character of the particles produced by the grinding had a material effect upon the results. A cement which was ground to pass, practically in its entirety, a 200-mesh sieve, did not, when mixed with sand and compared with a much coarser cement, give as good results in tensile strength as did the latter in similar mortar. This was demonstrated to be due to the presence of a greater amount of flour in the coarser cement. Fine grinding may mean too many particles of one size, and not enough flour which is really the thing that does the work. Of course, all such things should be considered in connection with improvements in the manufacture of cement.

Mr. Sprague. MR. L. G. SPRAGUE.—The remarks of Mr. Lesley are along the line I wished to speak on. It is a well-known fact that with the present sieving methods, the largest percentage passing a 100- or 200-mesh sieve does not always indicate the best cement. Until we can devise a good standard method which can readily be used by every one for testing the cement flour, I think that fineness is a question which should not be carried much farther.

TESTS OF PLAIN AND REINFORCED CONCRETE COLUMNS.

BY M. O. WITHEY.*

This paper reports tests on plain and reinforced concrete columns made in the laboratory for testing materials at the University of Wisconsin during the past year. Preliminary tests were first made upon 20 columns, A₁ to F₁, of the following five types:

1. Plain columns.
2. Columns reinforced with latticed angle, structural steel columns.
3. Columns reinforced with high carbon steel spirals.
4. Columns reinforced with spirals and vertical steel rods.
5. Columns reinforced with vertical steel rods and ties 1 ft. apart.

A more extended series of tests was then made on 32 columns containing spiral reinforcement, the variables being percentage of vertical steel, percentage of spiral steel, and richness of mix.

Due acknowledgment is hereby made to Dean F. E. Turneaure and Professor E. R. Maurer for valued suggestions received in making and reporting these tests, and to Mr. F. M. McCullough and Mr. A. H. Miller for assistance in performing the preliminary tests. Messrs. F. E. Bates, W. C. Mühlstein, A. R. Mitchell, W. W. Pugh, and A. C. Scherer, students in civil engineering, took for a thesis the subject of spiral reinforcement. They are deserving of much credit for the care which they exercised in making and testing columns G₁ to V₂. All spiral reinforcement was donated by "The American System of Reinforcing for Concrete Construction" of Chicago. Dean F. E. Turneaure contributed the structural steel columns used as reinforcement and the vertical steel rods.

Atlas Portland cement was used in the preliminary tests and Universal in the remainder. Both were tested and passed the specifications of this Society.

A local pit furnished a rather fine but fairly clean sand. It weighed about 107 lbs. per cu. ft. and contained 36 per cent. voids.

* In the absence of the author, this paper was read by Mr. F. E. Turneaure. —ED.

Crushed limestone was secured from a nearby quarry. In making columns G1 to N2, stone passing a 1-in. screen was used. This weighed 82 lbs. per cu. ft. and contained 50 per cent. voids. In all other columns where stone was used, the size was less than $1\frac{1}{4}$ ins., the weight 92 lbs. per cu. ft., and the voids 44 per cent.

Concrete was proportioned by volume, measured loose, cement being assumed to weigh 100 lbs. per cu. ft. Volumes were measured by weighing. All concrete was mixed for about three minutes in a No. 0 Smith mixer. After the dry materials had been thrown in and turned for about half a minute, water was admitted from a calibrated tank to both the mouth and hopper of the mixer. About 10 per cent. of the total weight of dry materials was found necessary to give a wet concrete which would flow easily around the reinforcement.

Table I contains values obtained from tensile tests of the steel reinforcement. One steel column of the same dimensions as those used to reinforce columns B1 to B4 was tested and showed an

TABLE I.—TENSION TESTS OF STEEL.

Size of Rod, ins.	No. of Tests.	Average Stress, lbs. per sq. in.	
		Yield Point.	Ultimate Strength.
$\frac{1}{4}$	2	47,400	62,000
$\frac{3}{8}$	9	45,000	65,400
$\frac{1}{2}$	6	41,600	61,300
$\frac{5}{8}$	8	44,000	63,100
$\frac{3}{4}$	7	40,300	61,900
1	8	44,300	66,400
$1\frac{1}{8}$	6	38,100	59,100
* No. 7 wire	9	96,100	132,100
† " " "	5	81,000	110,600
$\frac{1}{4}$	3	104,500	148,500

Values from tests of spiral wire are given below the double line.

elastic limit of 33,400 lbs. per sq. in., an ultimate strength of 48,000 lbs. per sq. in., and a modulus of elasticity of 26,000,000 lbs. per sq. in. Two $\frac{3}{4}$ by $\frac{3}{16}$ -in. pieces were cut from a portion of this column which did not appear overstressed and tested with the results shown in the table.

All columns with the same letter were made on the same day, care being taken to keep all conditions as uniform as possible.

* Wire from spirals with 1-in. pitch.

† Wire from spirals with 2-in. pitch.

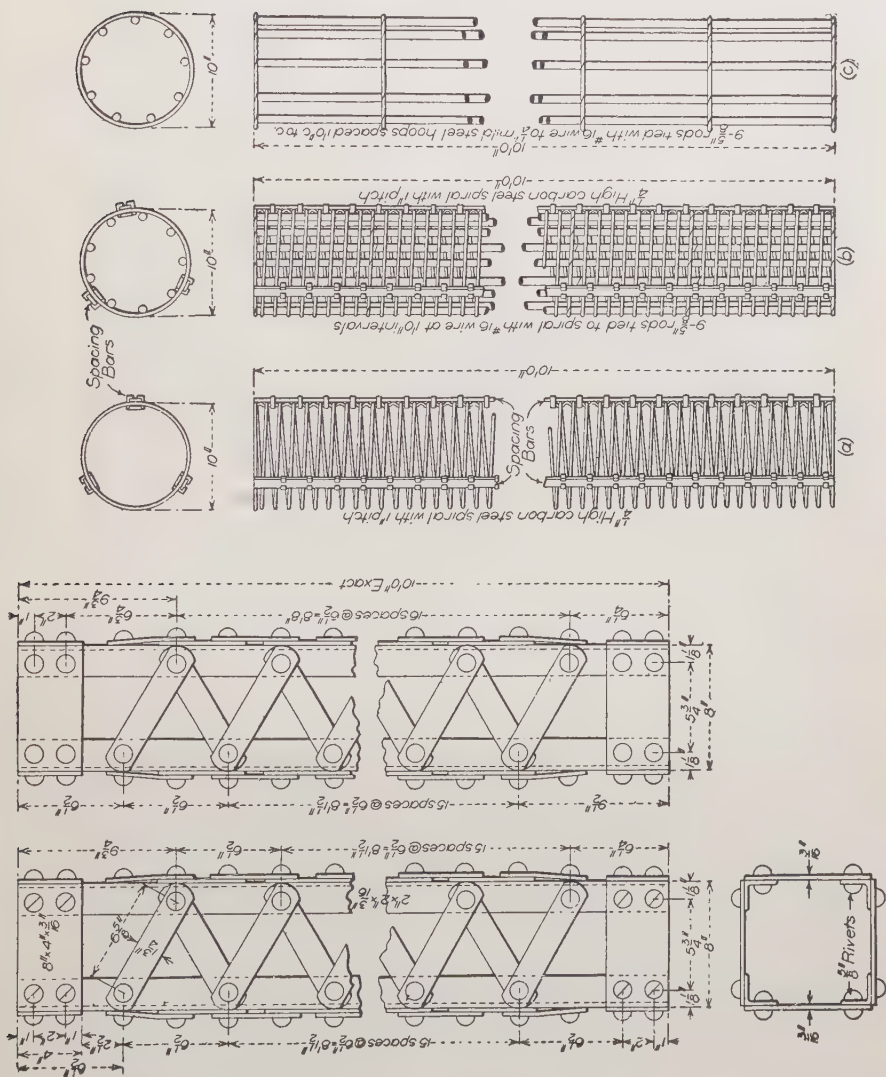


FIG. 1.—Types of Reinforcement Used in Preliminary Tests.

All columns of the preliminary series, A₁ to F₁, were 10 ft. long, columns A₁ to B₄ were squares 12 ins. on a side, C₁ to E₃ octagons 12 ins. on short diameters, while F₁ was a square 8 ins. on a side. The reinforced columns of this series were all made with a protective shell 1 or 2 ins. thick. In order to study the behavior of this shell and its effect on the strength of the test piece, it was removed from columns B₁, B₄, and C₁ before testing. The remaining columns, G₁ to W₃, were of circular cross section, 10½ ins. gross diameter and 8 ft. 6 ins. long. As the shell outside of the spiral added very little to the strength of the column, only the core area has been considered in computing stresses for these columns. All vertical reinforcement was milled to the required length. The types of reinforcement used in the different columns are shown in Fig. 1.* Table II gives properties of columns tested.

The columns of the preliminary series were made in wooden forms; all others were cast in molds of galvanized iron. These forms were set upon planed cast iron bed plates which were carefully leveled before the columns were poured. A compression cylinder 6 ins. in diameter and 18 ins. long was cast in an iron mold from every batch of concrete. A day or two after pouring, the columns and cylinders were capped with a thin layer of 1 : 1 mortar. While the mortar was still soft, a cast iron bed plate was placed upon it and carefully leveled. The depth of the mortar over the ends of the vertical reinforcement was made as small as possible. After 6 days the forms were removed from the specimens, which were then wet twice a day for one week and then sprinkled once a week until tested. The age at which specimens were tested varied from 50 to 65 days.

The columns were tested in the 600,000-lb. hydraulic testing machine in the laboratory. The lower head of this machine is rigidly fixed to the piston rod of an hydraulic jack, while the upper head is free to adjust itself to a specimen through a ball and socket joint. The columns were bedded at each end on cast iron plates covered with a thickness of blotting paper.

Stresses were applied at the rate of approximately 200 lbs. per sq. in. per minute, the increments of load being in general 15,000 lbs. Longitudinal deformations were measured on four

* Acknowledgment is made to the *Engineering Record* for the cuts used in this paper.—ED.

TABLE II.—PROPERTIES OF COLUMNS TESTED.

Age of Specimens, 2 Months.

Col. No.	Reinforcement.	Per Cent. Reinforcement.		Mix.	Shape of Cross Section.	Area, sq. ins.
		Vertical.	Lateral.			
1	2	3	4	5	6	7
A ₁	None	0	0	1 : 2 : 4	Square	144
A ₂		0	0	"	"	143
A ₃		0	0	"	"	142
A ₄		0	0	"	"	141
*B ₁	4—2 x 2 x $\frac{3}{16}$ -in. latticed angles.	4.5	....	"	"	64
B ₄		4.5	....	"	"	64
B ₂		2.0	....	"	"	142.5
B ₃		2.0	....	"	"	143
C ₁	$\frac{1}{2}$ -in. spiral, 1-in. pitch.	0	1.33	"	Octagonal	118
C ₂		0	1.33	"	"	118
C ₃		0	2.00	"	Round	78.5
C ₄		0	1.33	"	Octagonal	118
D ₁	9— $\frac{5}{16}$ -in. rods and $\frac{1}{2}$ -in. spiral, 1-in. pitch.	2.35	1.33	"	"	118
D ₂		2.35	1.33	"	"	118
D ₃		2.35	1.33	"	"	118
D ₄		2.35	1.33	"	"	118
E ₁	9— $\frac{5}{16}$ -in. rods with $\frac{1}{2}$ -in. ties, 1 ft. c. to c.	2.35	0.11	"	"	118
E ₂		2.35	0.11	"	"	118
E ₃		2.35	0.11	"	"	118
F ₁	None.	0	0	"	Square	64
H ₁	No. 7 wire spiral, 2-in. pitch. .	0	0.46	1 : 2 : 3 $\frac{1}{2}$	Round	78.5
H ₂		0	0.46	"	"	78.5
G ₁	8— $\frac{1}{2}$ -in. rods and No. 7 wire spiral, 2-in. pitch.	2.00	0.46	"	"	78.5
G ₂		2.00	0.46	"	"	78.5
I ₁	8— $\frac{1}{2}$ -in. rods and No. 7 wire spiral, 2-in. pitch.	3.78	0.46	"	"	78.5
I ₂		3.78	0.46	"	"	78.5
J ₁	8— $\frac{3}{8}$ -in. rods and No. 7 wire spiral, 2-in. pitch.	6.11	0.46	"	"	78.5
J ₂		6.11	0.46	"	"	78.5
L ₁	No. 7 wire spiral, 1-in. pitch. .	0	0.92	"	"	78.5
L ₂		0	0.92	"	"	78.5
K ₁	8— $\frac{1}{2}$ -in. rods and No. 7 wire spiral, 1-in. pitch.	2.00	0.92	"	"	78.5
K ₂		2.00	0.92	"	"	78.5
N ₁	8— $\frac{1}{2}$ -in. rods and No. 7 wire spiral, 1-in. pitch.	3.78	0.92	"	"	78.5
N ₂		3.78	0.92	"	"	78.5
M ₁	8— $\frac{3}{8}$ -in. rods and No. 7 wire spiral, 1-in. pitch.	6.11	0.92	"	"	78.5
M ₂		6.11	0.92	"	"	78.5
P ₁	8—1-in. rods and No. 7 wire spiral, 1-in. pitch.	8.00	0.92	1 : 2 : 4	"	78.5
P ₂		8.00	0.92	"	"	78.5
O ₁	8— $\frac{1}{2}$ -in. rods and $\frac{1}{2}$ -in. spiral, 1-in. pitch.	6.11	1.96	"	"	78.5
O ₂		6.11	1.96	"	"	78.5
R ₁	8—1-in. rods and $\frac{1}{2}$ -in. spiral, 1-in. pitch.	8.00	1.96	"	"	78.5
R ₂		8.00	1.96	"	"	78.5
Q ₁	8—1 $\frac{1}{2}$ -in. rods and $\frac{1}{2}$ -in. spiral, 1-in. pitch.	10.12	1.96	"	"	78.5
Q ₂		10.12	1.96	"	"	78.5
S ₁	No. 7 wire spiral, 1-in. pitch. .	0	0.92	1 : 1 : 2	"	78.5
S ₂		0	0.92	"	"	78.5
T ₁	8— $\frac{3}{8}$ -in. rods and No. 7 wire spiral, 1-in. pitch.	6.11	0.92	"	"	78.5
T ₂		6.11	0.92	"	"	78.5
V ₁	No. 7 wire spiral, 1-in. pitch. .	0	0.92	1 : 1 $\frac{1}{2}$	"	78.5
V ₂		0	0.92	"	"	78.5
U ₁	8— $\frac{3}{8}$ -in. rods and No. 7 wire spiral, 1-in. pitch.	6.11	0.92	"	"	78.5
U ₂		6.11	0.92	"	"	78.5
W ₁	None	0	0	1 : 2 : 4	"	86.6
W ₂		0	0	"	"	86.6
W ₃		0	0	"	"	86.6

*Although the lacing bars produced lateral restraint on these columns no account of it has been taken in computing results.

sides of a column by means of copper wire dial compressometers. Readings were taken to 0.0001 in. over gage lengths of 66 ins. for the 8½-ft. columns, and 80 ins. for the 10-ft. columns. Fig. 2

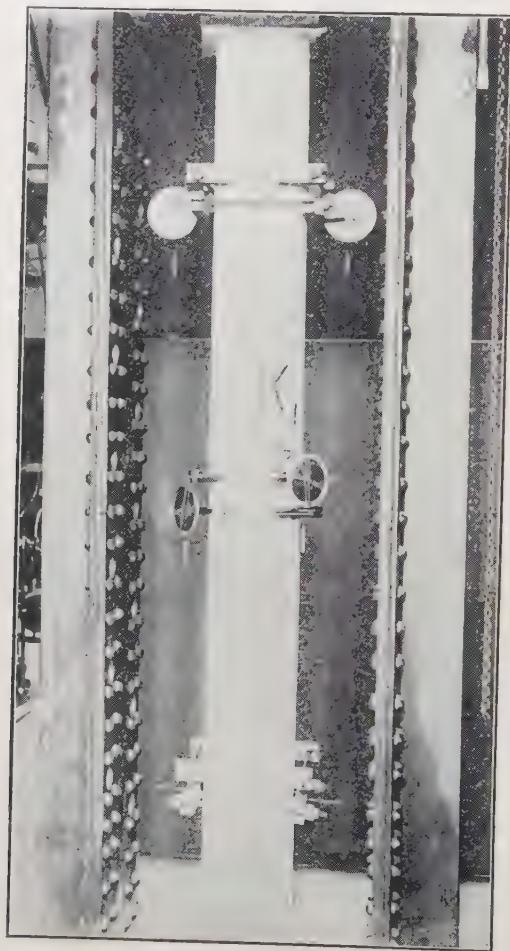


FIG. 2.—Column K1 ready to be Tested

shows column K1 fitted with apparatus ready to be tested. Measurements of lateral deformations at the middle of a column were made on columns G2 to W3 by means of the ring-shaped

apparatus which may be seen in Fig. 2, one of which is shown more in detail in Fig. 3. The main part of one of these devices consisted of a welded steel ring which encircled the column and was held in position by the pivots *pp* and the screw *s*. The pivots *pp* rested against springs coiled in the cylindrical cups *cc*. Screws in the ends of these cups served to regulate the pressure of the springs upon the pivots. These springs took up the swelling of the column without disturbing the position of the ring vertically. As a 1-lb.

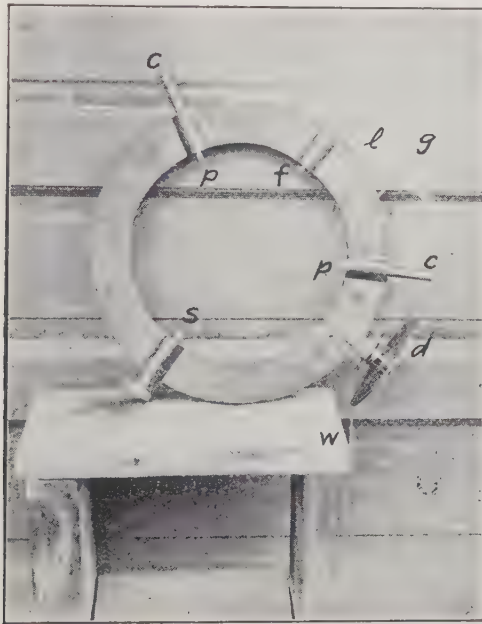


FIG. 3.—Device for Measuring Lateral Deformations.

force deformed a spring about 0.01 in., and the same force applied along a diameter would deform the ring only 0.000003 in., it will be seen that the change in dimensions of the ring during a test were negligible. The deformation between the screw *s* and the sliding fulcrum *f* was multiplied five times by the lever *l* and transmitted to the dial *d* through a No. 36 covered copper wire held taut by the weight *w*. The guide *g* afforded a knife-edged support for the aluminum lever *l* to slide upon. A careful cali-

bration of this device showed that it was quite sensitive and that the probable error of a single observation was less than 5 per cent.

Only a brief discussion of main features of the tests will follow. A more complete account of the preliminary series may be found in Bulletin No. 300, University of Wisconsin, now in press. The tests on spiral columns will be completely reported in a bulletin to be issued later in the year.

The 1 : 2 : 4 plain concrete columns, A₁ to A₄, had an average ultimate strength of 2,070 lbs. per sq. in., the maximum variation from this value, as may be seen in Table III, being only 2 per cent. Columns W₁ to W₃, also of 1 : 2 : 4 mix and unreinforced, were exceptionally strong for the class of materials employed, showing an average ultimate strength of 2,600 lbs. per sq. in. As these three columns were made of a concrete much superior to that in any of the other columns made from 1 : 2 : 4 or 1 : 2 : 3½ mix, they cannot satisfactorily be compared with them. Failures of all plain columns were sudden and without any warning.

Columns B₁ to B₄ exhibited considerably more toughness than did the plain columns. Columns B₁ and B₄, outside shell removed and containing 4.5 per cent. vertical reinforcement in the form of structural steel columns, sustained an average ultimate load of 239,500 lbs. (3,740 lbs. per sq. in.). The plain concrete column F₁ of the same size sustained 120,600 lbs. The steel column similar to the reinforcement in these columns failed under a load of 138,000 lbs. A comparison of these figures indicates the value of the reinforcement and also shows a means of increasing the strengths of hollow steel columns by filling the inside with concrete. In the tests of columns B₂ and B₃, the area of the outside shell was so large in proportion to the area of the core that the value of this form of reinforcement was obscured. The results of tests of these two columns, together with those of columns B₁ and B₄, indicate that the protective shell does not carry its share of the load in this type of column, especially when there is relatively little direct bond between it and the concrete core. This fact was more firmly established by a re-test on B₂. As soon as the maximum load on this column, 303,000 lbs., was reached, the pressure was immediately released and the protective shell knocked off. The load was again applied and the column failed at 246,000 lbs. A com-

TABLE III.—STRENGTHS OF COLUMNS AND AUXILIARY COMPRESSION CYLINDERS.

Col. No.	Per Cent. Reinforcement.		Maximum Load, lbs. (P)	Ultimate Strength, lbs. per sq. in.†	Load at Yield Point, lbs. (P ₁)	Stress at Yield Point, lbs. per sq. in. in Gross Section.	$\frac{P_1}{P}$	Compressive Strength of Cylinders, lbs. per sq. in. (C)
	Vertical.	Lateral.						
1	2	3	4	5	6	7	8	9
A ₁	0	0	294,000	2,040	.....	.....	.....	2,430
A ₂	0	0	303,000	2,110	.....	.....	.....	2,400
A ₃	0	0	292,000	2,055	.....	.....	.....	2,240
A ₄	0	0	294,000	2,080	.....	.....	.....	2,360
*B ₁	4.5	.....	237,000	3,700	183,000	2,860	0.77	2,270
*B ₄	4.5	.....	242,000	3,780	183,000	2,860	0.76	2,140
B ₂	2.0	.....	303,000	2,125	273,000	1,920	0.90	2,640
B ₃	2.0	.....	288,000	2,015	280,000	1,960	0.97	2,200
C ₁	0	1.33	366,000	4,660	213,000	1,800	0.88	2,280
C ₂	0	1.33	345,000	4,390	183,000	1,550	0.53	2,190
*C ₃	0	2.00	288,000	3,660	153,000	1,950	0.53	2,180
C ₄	0	1.33	268,000	3,410	183,000	1,550	0.68	2,150
D ₁	2.35	1.33	351,000	4,470	258,000	2,180	0.74	2,150
D ₂	2.35	1.33	330,000	4,200	273,000	2,310	0.83	2,130
D ₃	2.35	1.33	391,000	4,970	303,000	2,560	0.77	2,380
D ₄	2.35	1.33	421,000	5,360	288,000	2,440	0.68	2,350
E ₁	2.35	0.11	273,000	2,310	273,000	2,310	1.00	2,430
E ₂	2.35	0.11	273,000	2,310	273,000	2,310	1.00	2,430
E ₃	2.35	0.11	318,000	2,695	318,000	2,695	1.00	2,040
F ₁	0	0	120,600	1,880	.....	.....	.....	2,230
H ₁	0	0.46	183,000	2,330	153,000	1,950	0.84	2,040
H ₂	0	0.46	168,000	2,140	138,000	1,760	0.82	1,460
G ₁	2.00	0.46	261,000	3,320	213,000	2,710	0.82	2,100
G ₂	2.00	0.46	258,000	3,280	213,000	2,710	0.83	1,420
I ₁	3.78	0.46	333,000	4,240	288,000	3,660	0.87	2,240
I ₂	3.78	0.46	321,000	4,080	258,000	3,280	0.80	2,120
J ₁	6.11	0.46	408,000	5,100	333,000	4,240	0.82	2,110
J ₂	6.11	0.46	397,500	5,050	333,000	4,240	0.84	2,000
L ₁	0	0.92	210,900	2,680	108,000	1,370	0.51	1,780
L ₂	0	0.92	204,000	2,600	108,000	1,370	0.53	1,760
K ₁	2.00	0.92	318,000	4,050	213,000	2,710	0.67	2,100
K ₂	2.00	0.92	295,500	3,760	198,000	2,520	0.67	1,890
N ₁	3.78	0.92	318,000	4,050	273,000	3,470	0.86	1,880
N ₂	3.78	0.92	340,500	4,340	258,000	3,280	0.76	1,720
M ₁	6.11	0.92	376,500	4,790	303,000	3,860	0.81	1,660
M ₂	6.11	0.92	360,000	4,580	288,000	3,660	0.80	1,710
P ₁	8.00	0.92	531,300	6,760	438,000	5,560	0.82	2,380
P ₂	8.00	0.92	556,500	7,090	453,000	5,760	0.81	2,350
O ₁	6.11	1.96	511,500	6,510	333,000	4,240	0.65	2,270
O ₂	6.11	1.96	522,000	6,650	363,000	4,620	0.70	2,600
R ₁	8.00	1.96	570,000	7,250	303,000	5,000	0.69	2,310
R ₂	8.00	1.96	525,000	6,680	423,000	5,380	0.80	2,460
Q ₁	10.12	1.96	486,000	6,190	408,000	5,190	0.84	2,280
Q ₂	10.12	1.96	627,000	7,990	498,000	6,340	0.79	2,330
S ₁	0	0.92	468,000	5,950	303,000	3,860	0.65	4,060
S ₂	0	0.92	453,000	5,760	333,000	4,240	0.74	4,080
T ₁	6.11	0.92	588,000	7,480	453,000	5,760	0.77	4,720
T ₂	6.11	0.92	558,000	7,100	453,000	5,760	0.81	4,080
V ₁	0	0.92	453,000	5,760	288,000	3,660	0.64	4,820
V ₂	0	0.92	387,000	4,920	273,000	3,480	0.71	4,930
U ₁	6.11	0.92	633,000	8,050	468,000	5,950	0.74	4,900
U ₂	6.11	0.92	648,000	8,250	468,000	5,950	0.72	4,210
W ₁	0	0	237,000	2,660	.....	.....	.....	2,600
W ₂	0	0	237,000	2,660	.....	.....	.....	2,400
W ₃	0	0	214,500	2,480	.....	.....	.....	2,250

*Outside shell removed before testing.

†Ultimate strengths for columns C₁ to D₄=maximum load ÷ core area.

parison of the stresses sustained by the column before and after the shell was removed show that the shell sustained only about 40 per cent. of the average unit stress carried by the entire cross

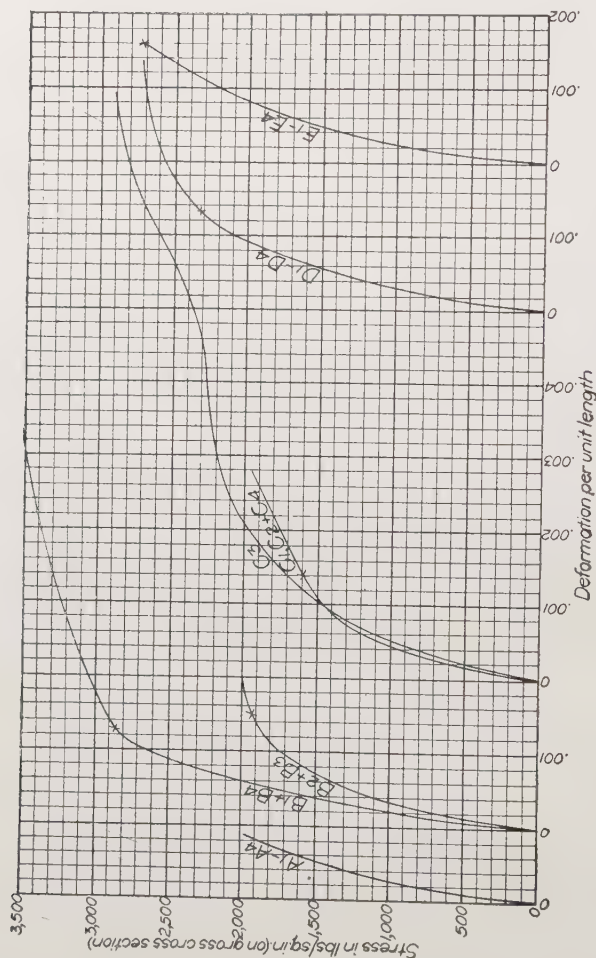


FIG. 4.—Average Stress-Deformation Curve for Preliminary Series.

section. However, tests of these two columns revealed that the protective shell remained intact until the yield point of the steel was passed. The point on the stress-deformation curve at which this outside coating began to crack is indicated by a cross in Fig. 4.

These tests demonstrate that this type of column possesses considerable toughness and a high load-carrying capacity; that the steel and concrete act together in carrying the load and in resisting deformation; and that the protective coating, although it remains intact until the yield point of the steel is passed, should not be counted upon to resist deformations or stresses.

Columns E₁ to E₃ exhibited considerable stiffness when tested. No cracks of any consequence appeared until the deformations indicated that the yield point of the steel had been reached. At this point, however, owing to insufficient lateral support offered by the widely separated $\frac{1}{4}$ -in. ties, they failed very suddenly. The increase in strength for each per cent. of longitudinal reinforcement for these columns over the strength of the plain columns A₁ to A₄, is approximately 156 lbs. per sq. in. These columns were lacking in toughness and did not have a high ultimate strength.

The preliminary tests of the spiral columns C₁ to D₄ demonstrated that this type of column has great toughness and a high ultimate strength, which is accompanied by large deformations and deflections. By comparing the test records and the stress-deformation curves for columns D₁ to D₄, which had vertical reinforcement, it was observed that the outside shell of concrete cracked at about the same time that the stress in the steel reached the yield point. As may be seen in Fig. 4, the stress-deformation curves for columns C₁ to C₄ are practically the same up to a stress of 1,600 lbs. per sq. in. As the shell concrete in columns C₁, C₂, and C₄ cracked at about this stress, it seems evident that the shell and core act in unison up to this point in this type of column. However, as the shell on a column in a building is liable to be greatly weakened by a fire, its strengthening and stiffening value should be neglected in such design.

In order to more easily analyze the distribution of stress and deformation, columns H₁ to V₂ were made with practically no outside shell. The general characteristics of columns H₁ to R₂ under test were similar to those exhibited in the tests of C₁ to D₄. In two instances the spirals broke after the maximum load had been passed, and the deformations became excessive. Fig. 5 shows column J₂ after failure. This is typical of many of the columns tested. Columns S₁ to V₂, made from rich mixes of concrete, were considerably stiffer than the 1 : 2 : 3 $\frac{1}{2}$ columns similarly

reinforced. Instead of the bulging failure found in the columns of leaner mix, a shearing failure of the concrete was plainly evident in several of these columns.



FIG. 5.—Column J₂ after Failure.

Figs. 6 and 7 show the longitudinal and lateral stress-deformation curves for columns H₁, H₂, I₁, and I₂. The points in the longitudinal stress-deformation curves are encircled with a single

line. As may be seen from these figures, the yield point is more pronounced in the columns with vertical reinforcement. The break in the longitudinal stress-deformation curve occurs at prac-

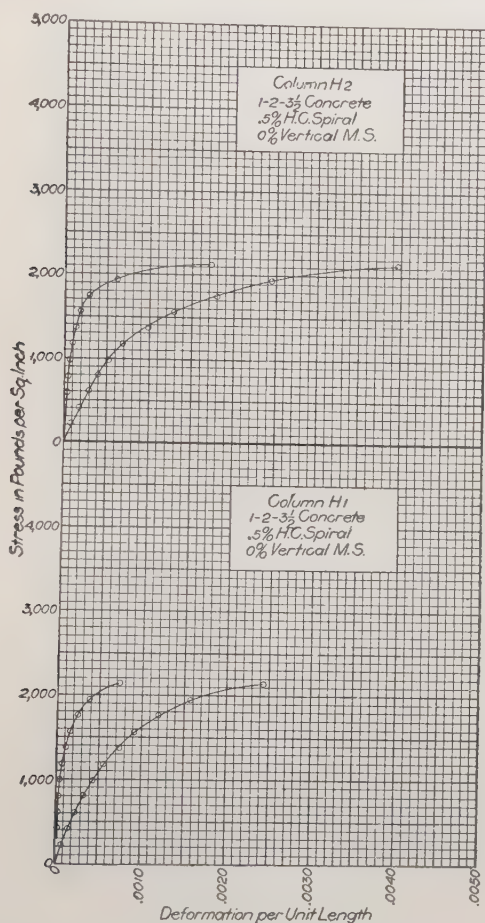


FIG. 6.—Stress-Deformation Curves for Columns H₁ and H₂.

tically the same stress as the break in the lateral stress-deformation curve.

Fig. 8 contains the curves for column U₂, the strongest column tested. The maximum load, 648,000 lbs., or 8,250 lbs.

per sq. in., was applied six times and maintained on the column for 17 minutes on the last application before the column failed. Figs. 6, 7, and 8 contain characteristic curves for these types of columns.

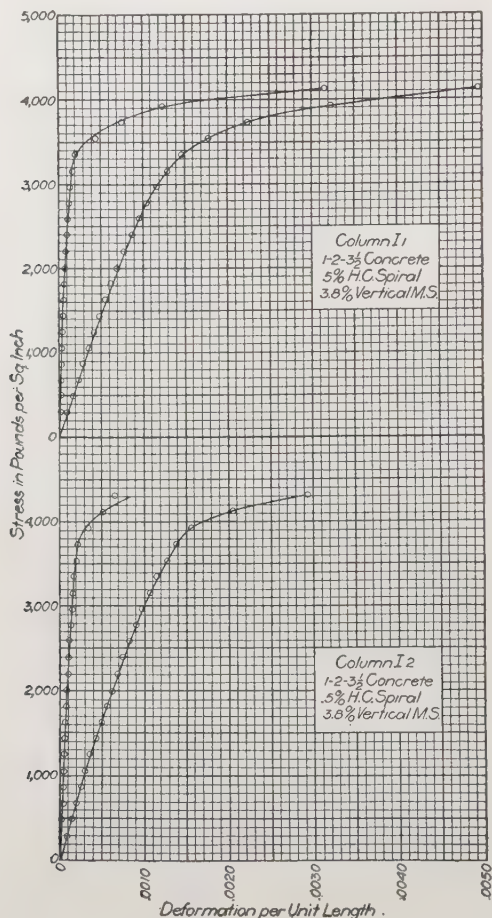


FIG. 7.—Stress-Deformation Curves for Columns I₁ and I₂.

The strengths of columns H₁ to V₂ will be found in Table III. No allowance has been made for the strength of the thin shell outside of the spiral in computing stresses for these columns. The stresses given in this table are figured on the entire area inside of the spiral.

Table IV contains stresses in concrete and steel at the yield point. Stresses in the vertical steel were obtained by multiplying the unit longitudinal deformation by the modulus of elasticity, 30,000,000 lbs. per sq. in. Stresses in the spiral were

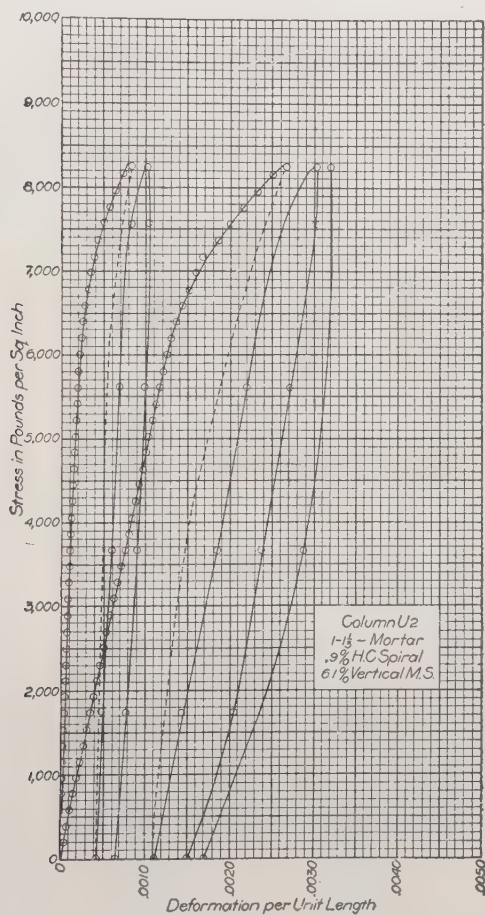


FIG. 8.—Stress-Deformation Curves for Column U2.

computed by multiplying the unit lateral deformation by the same quantity. Stresses in the concrete were found by deducting the total stress in the vertical steel from the total stress in the gross section and dividing by the area of the concrete. The ninth

division in Table IV contains ratios of average strength of cylinders to stress in the concrete of the corresponding column at yield point.

Table V gives values of the modulus of elasticity, Poisson's ratio, and the ratio of the modulus of elasticity of steel to that of concrete, viz., n , computed at one-fourth of the ultimate load, and

TABLE IV.—STRESSES IN CONCRETE AND STEEL AT YIELD POINT FOR COLUMNS H₁ TO W₃.

Col. No.	Per Cent. Reinforcement.		Stresses at Yield Point, lbs. per sq. in.				Compressive Strength of Cylinders, lbs. per sq. in. (C)	C f _c
	Vertical.	Lateral.	In Gross Section.	In Steel.		In Concrete. (f _c)		
				Vertical.	Lateral.			
1	2	3	4	5	6	7	8	9
H ₁	0	0.46	1,950	.....	11,400	1,950	2,040	1.05
H ₂	0	0.46	1,760	.....	8,700	1,760	1,460	0.83
G ₁	2.00	0.46	2,710	40,500	.....	1,940	2,100	1.08
G ₂	2.00	0.46	2,710	40,500	12,000	1,940	1,420	0.73
I ₁	3.78	0.46	3,660	40,500	6,900	2,220	2,240	1.01
I ₂	3.78	0.46	3,280	43,500	6,000	1,700	2,120	1.25
J ₁	6.11	0.46	4,240	40,500	6,300	1,870	2,110	1.13
J ₂	6.11	0.46	4,240	40,800	6,000	1,850	2,000	1.08
L ₁	0	0.92	1,370	.....	4,800	1,370	1,780	1.30
L ₂	0	0.92	1,370	.....	4,800	1,370	1,760	1.28
K ₁	2.00	0.92	2,710	39,000	6,900	1,970	2,100	1.07
K ₂	2.00	0.92	2,520	39,900	7,200	1,760	1,890	1.07
N ₁	3.78	0.92	3,470	37,500	6,300	2,130	1,880	0.88
N ₂	3.78	0.92	3,280	39,900	7,500	1,840	1,720	0.93
M ₁	6.11	0.92	3,860	38,100	5,400	1,650	1,660	1.01
M ₂	6.11	0.92	3,660	37,200	7,500	1,480	1,710	1.16
P ₁	8.00	0.92	5,560	39,300	7,500	2,630	2,380	0.91
P ₂	8.00	0.92	5,760	39,000	8,700	2,870	2,350	0.82
O ₁	6.11	1.96	4,240	36,600	9,000	2,130	2,270	1.07
O ₂	6.11	1.96	4,620	37,200	7,800	2,490	2,690	1.08
R ₁	8.00	1.96	5,000	36,900	7,500	2,230	2,310	1.04
R ₂	8.00	1.96	5,380	38,100	9,000	2,540	2,460	0.97
Q ₁	10.12	1.96	5,190	35,400	6,600	1,790	2,280	1.27
Q ₂	10.12	1.96	6,340	39,000	6,900	2,670	2,330	0.87
S ₁	0	0.92	3,860	.....	7,500	3,860	4,060	1.05
S ₂	0	0.92	4,240	.....	7,200	4,240	4,080	0.97
T ₁	6.11	0.92	5,760	36,900	6,900	3,730	4,720	1.27
T ₂	6.11	0.92	5,760	37,200	7,800	3,720	4,080	1.10
V ₁	0	0.92	3,660	.....	7,800	3,660	4,820	1.32
V ₂	0	0.92	3,480	.....	5,700	3,480	4,930	1.42
U ₁	6.11	0.92	5,950	35,400	6,900	4,040	4,000	1.21
U ₂	6.11	0.92	5,950	37,500	6,600	3,900	4,210	1.08

also the value of n at the yield point. The values of the modulus for columns H₁ to R₂ contained in division 6 have been plotted in Fig. 9 as ordinates, with the corresponding percentages of vertical reinforcement as abscissas. It will be noted that the values lie between the theoretical lines drawn for $n=10$ and $n=15$. The

average value of n , shown by the circles, decreases slightly as the percentage of vertical reinforcement, or the size of rod, increases.

Division 5, Table IV, shows that humps in the stress-deformation curves indicate that the yield point of the steel had been

TABLE V.—ELASTIC PROPERTIES OF COLUMNS H₁ TO W₃.

Moduli of Elasticity—Poisson's Ratio—Values of n .

Col. No.	Per Cent. Reinforcement.		Ultimate Strength, lbs. per sq. in.	Stress at Yield Point in Gross Section, lbs. per sq. in.	Modulus of Elasticity at $\frac{1}{2}$ Ultimate Strength, lbs. per sq. in.	Poisson's Ratio at $\frac{1}{2}$ Ultimate Strength.	$E_s = n$ at $\frac{1}{2}$ Ultimate Strength.	n at Yield Point
	Vertical.	Lateral.						
1	2	3	4	5	6	7	8	9
H ₁	0	0.46	2,330	1,950	2,500,000	0.14	12	24
H ₂	0	0.46	2,140	1,760	2,200,000	0.114	14	30
G ₁	2.00	0.46	3,320	2,710	3,300,000	....	11	21
G ₂	2.00	0.46	3,280	2,710	3,400,000	0.11	11	21
I ₁	3.78	0.46	4,240	3,660	3,700,000	0.14	11	18
I ₂	3.78	0.46	4,080	3,280	3,100,000	0.08	15	26
J ₁	6.11	0.46	5,190	4,240	4,500,000	0.09	11	22
J ₂	6.11	0.46	5,050	4,240	4,200,000	0.085	12	22
L ₁	0	0.92	2,680	1,370	2,200,000	0.155	14	19
L ₂	0	0.92	2,600	1,370	2,000,000	0.137	15	20
K ₁	2.00	0.92	4,050	2,710	2,900,000	0.110	13	20
K ₂	2.00	0.92	3,760	2,520	2,700,000	0.135	14	23
N ₁	3.78	0.92	4,050	3,470	4,050,000	0.100	10	18
N ₂	3.78	0.92	4,340	3,280	3,550,000	0.16	12	22
*M ₁	6.11	0.92	4,790	3,860	3,050,000	0.083	23	23
M ₂	6.11	0.92	4,580	3,660	3,800,000	0.118	14	25
P ₁	8.00	0.92	6,760	5,560	5,200,000	0.123	9.9	15
P ₂	8.00	0.92	7,090	5,760	5,400,000	0.119	9.2	14
O ₁	6.11	1.96	6,510	4,240	4,600,000	0.129	10	17
O ₂	6.11	1.96	6,650	4,620	4,700,000	0.132	9.8	15
R ₁	8.00	1.96	7,250	5,000	5,250,000	0.117	9.8	17
R ₂	8.00	1.96	6,680	5,380	5,250,000	0.138	9.8	15
Q ₁	10.12	1.96	6,190	5,190	5,200,000	0.088	12	19
Q ₂	10.12	1.96	7,990	6,340	5,800,000	0.101	9.8	15
S ₁	0	0.92	5,950	3,860	3,900,000	0.151	7.7	10
S ₂	0	0.92	5,760	4,240	4,350,000	0.117	6.9	8.8
T ₁	6.11	0.92	7,480	5,760	5,350,000	0.15	8	9.9
T ₂	6.11	0.92	7,100	5,760	5,000,000	0.134	8.9	10
V ₁	0	0.92	5,760	3,660	3,400,000	0.156	8.8	10
V ₂	0	0.92	4,920	3,480	3,400,000	0.113	8.8	11
U ₁	6.11	0.92	8,050	5,950	5,500,000	0.143	7.7	8.8
U ₂	6.11	0.92	8,250	5,950	5,000,000	0.106	8.9	9.6
W ₁	0	0	2,660	....	3,700,000	0.137	8.1	....
W ₂	0	0	2,660	....	3,600,000	0.112	8.3	....
W ₃	0	0	2,480	....	3,200,000	0.095	9.4	....

reached. Division 9 of this table demonstrates that practically the full compressive strength of the concrete in the column had been developed at the same time. Division 6 of the same table

* Load of 300,000 lbs. was accidentally applied before test was begun.

shows that the stresses in the spiral at the yield point were small. The ratio of the values in division 6 to those in division 5 is Poisson's ratio at the yield point of the column. A common formula for determining the increase in strength due to spiral reinforcement is

$$*f'_c = \left(1 + \frac{\mu n p'}{2} \right) f_c$$

In this formula, f'_c = total longitudinal unit stress, μ = Poisson's ratio, n = ratio of the modulus of elasticity of steel to that of

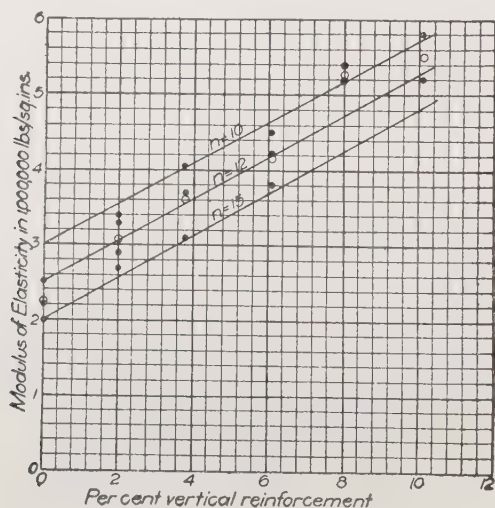


FIG. 9.—Effect of Vertical Reinforcement on the Modulus of Elasticity of Columns.

concrete, p' = percentage of closely spaced lateral reinforcement, and f_c = longitudinal unit stress not balanced by the lateral compressive unit stress. Using this formula, the maximum increase in strength at the yield point due to spiral reinforcement is only about 4 per cent., a value which is found for column O1. This demonstrates conclusively that the yield point of the column is practically independent of the percentage of spiral reinforcement.

In order to derive constants for formulas which would apply to the results of these tests, the columns containing the same

* See Turneure and Maurer's "Principles of Reinforced Concrete Construction," p. 110.

percentage of spiral reinforcement and made of the same grade of concrete have been grouped together and the values of unit stress at yield point and ultimate strength plotted in Fig. 10 as ordinates, with the corresponding percentages of vertical reinforcement as abscissas. The general equation used for the stress at the yield point is

$$\frac{P_1}{A} = (1-p) f_c + p f_s \dots \dots \dots (a)$$

and at the ultimate strength it is

$$\frac{P}{A} = (1-p) f_c + p f_s + k \sqrt{p'} f'_s \dots \dots \dots (b)$$

In these formulas, P_1 = load at yield point, P = maximum load, A = area of column inside of spiral, p = percentage of longitudinal steel, p' = percentage of lateral steel, f_c = ultimate compressive strength of concrete, f_s = yield point of longitudinal steel, f'_s = yield point of lateral steel, and k = constant.

The equations for the columns with 0.5 per cent. spiral reinforcement are:

$$\frac{P_1}{A} = (1-p) 1900 + 41500 p \dots \dots \dots (a')$$

$$\frac{P}{A} = (1-p) 1900 + 41500 p + 0.12 \sqrt{0.0046} \times 81000 \dots \dots \dots (b')$$

For those with 0.9 per cent. spiral:

$$\frac{P_1}{A} = (1-p) 1900 + 38700 p \dots \dots \dots (a'')$$

$$\frac{P}{A} = (1-p) 1900 + 38700 p + 0.12 \sqrt{0.0092} \times 96000 \dots \dots \dots (b'')$$

For those with 2 per cent. spiral:

$$\frac{P_1}{A} = (1-p) 2250 + 37200 p \dots \dots \dots (a''')$$

$$\frac{P}{A} = (1-p) 2250 + 37200 p + 0.12 \sqrt{0.0196} \times 104500 \dots \dots \dots (b''')$$

The values of f_s and f_c in these equations were obtained by averaging the values in divisions 5 and 7 respectively of Table IV for each group of specimens; the values of f'_s are given in Table I. These equations are plotted in Fig. 10.

From the results of these tests the following conclusions seem evident:

1. A small amount, 0.5 to 1 per cent., of closely spaced lateral reinforcement, such as the spirals used, will greatly increase the toughness and ultimate strength of a concrete

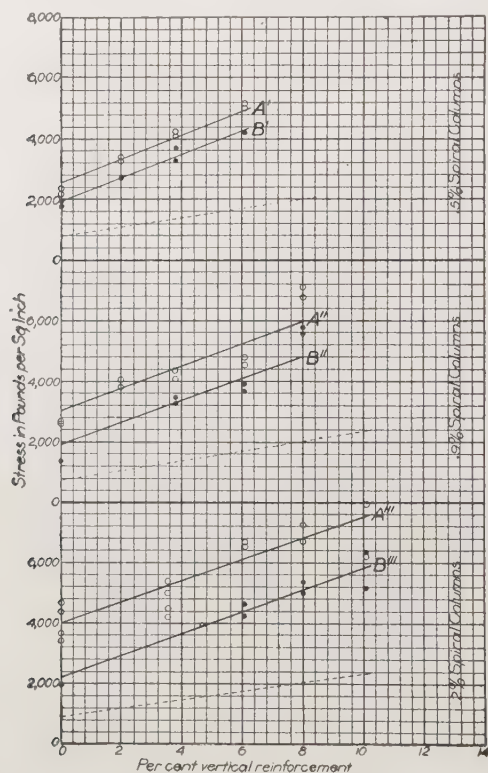


FIG. 10.—Effect of Percentage of Reinforcement on the Strength of Columns.

column, but does not materially affect the yield point. More than 1 per cent. of lateral reinforcement does not appear to be necessary. The use of lateral reinforcement alone does not seem advisable.

2. Vertical steel in combination with such a lateral reinforcement raises the yield point and ultimate strength of the column

and increases its stiffness. Columns reinforced with vertical steel only are brittle and fail suddenly when the yield point of the steel is reached, but are considerably stronger than plain columns made from the same grade of concrete.

3. Increasing the amount of cement in a spirally reinforced column increases the strength and stiffness of the column. A column made of rich concrete or mortar and containing small percentages of longitudinal and lateral reinforcement, is without doubt fully as stiff and strong and more economical than one made from a leaner mix reinforced with considerably more steel. In these tests, doubling the amount of cement increased the yield point and ultimate strength of the columns without vertical steel about 100 per cent., and added about 50 per cent. to the strength of those reinforced with 6.1 per cent. vertical steel. (See columns L, M, and S to V).

4. From the behavior under test of the columns reinforced with spirals and vertical steel and the results computed, it would seem that a static load equal to from 35 to 40 per cent. of the yield point would be a safe working load. As the ultimate strength of the concrete and the yield point of the steel are generally known or can be assumed with fair accuracy, formula (a) can be readily used to determine the working load. The dotted lines in Fig. 10 represent working values of P/A equal to 40 per cent. of the yield point load.

5. The results obtained from tests of columns reinforced with structural steel indicate that such columns have considerable strength and toughness, and that the steel and concrete core act in unison up to the yield point of the former. The shell concrete will remain intact until the yield point of the steel is reached, but no allowance should be made for its strength or stiffness.

6. As many of the blotters on the tops and bottoms of columns bore imprints of the vertical steel after failure, it would seem a safe precaution to use bed plates at the foundations for such columns, and thus prevent any possibility of the steel punching through the concrete under an excessive load.

DISCUSSION.

Mr. Talbot. MR. A. N. TALBOT.—We have made at the University of Illinois during the last year several series of tests on columns covering some of the same ground as the tests which have been explained by Mr. Turneure. We have made tests upon columns reinforced with spirals alone, reinforced with spirals and longitudinal, reinforced with longitudinal alone, and reinforced with structural shapes.

Of the columns reinforced with spirals alone perhaps the most novel feature is found in the series in which the variable was the length of column. The columns were each 12 ins. in diameter, with 1.5 per cent. spiral reinforcement, the spirals being spaced at 1-in. pitch. Four lengths of columns were used, 5 ft., 10 ft., 15 ft., and 20 ft. The effect of length may be shown by a diagram, the ordinates representing the load carried, and the abscissas the length of column. The plotted points for the tests lie almost exactly in a straight line inclining diagonally downward. The load for the 5-ft. length was something like 4,800 lbs. per sq. in., and for the 20-ft. length about 2,300 lbs. per sq. in. If we prolong the line, we shall find that for a column 34 ft. long there would be no strength. If now on this diagram be plotted what Mr. Turneure has named the "yield point," but which I have termed the ultimate strength of the concrete alone (without hooping), the line runs across nearly horizontally at about 1,800 lbs. per sq. in., possibly dropping down a little. Above this line the hooping is brought into action. The decrease in ultimate strength with increased length is to be expected, since it is known that the stiffness of the hooped column is very small. Instead of having a modulus of elasticity of 2,500,000 or 3,000,000, as is the case with ordinary concrete and as is true up to the yield point of the hooped concrete, the ratio of added stress to added deformation may be as small as 165,000, so that we have a column which, above the yield point, is only one-eighteenth as stiff as a plain concrete column. Therefore we must expect that the conditions necessary for the "long column" formula will be

found in columns of medium length. Under the conditions of these tests a hooped column 24 ft. long would be no stronger than a plain concrete column, although it would not fail so suddenly. Mr. Talbot.

In a series of tests to find the effect of spacing of hooping, the pitch of the spirals was made 1 in., 2 ins., 3 ins., and 4 ins. It was apparent that with spirals having a pitch of about 6 or 7 ins., the effect would be small. The spiral with 1-in. pitch would probably not differ much in strength from a closer spacing.

Now in both series of tests, the feature which was apparent was the lateral deflection of the column. In the long column, soon after the ordinary limit of strength of plain concrete was reached, the column began to deflect, and the deflection was visible at a very much lower load than in the short column. In the same way, with the columns having variable pitch those with the spacing far apart gave considerable deflections at relatively low loads.

In repetitive loading of hooped columns, it was found that the effect of repeating the load was very marked, and in some cases with fifty repetitions of a load somewhat beyond this yield point—I do not recall the figures exactly—the deformation kept on increasing, and there seemed to be little indication of its becoming a constant quantity.

In the columns which were reinforced both spirally and longitudinally, we did not have as uniform results with 8 per cent. of longitudinal reinforcement as has been reported by Mr. Turneure. The lower reinforcements gave results quite close to each other, but with the larger reinforcements the results were not concordant. A study of them seems to show that for the larger reinforcement there was not always the same distribution of stress between the steel and the concrete which was had with the smaller reinforcement.

In the columns reinforced with structural shapes we did not get the hooping effect which has been described. We obtained the highest load in almost every case as soon as the columns reached a deformation such that the steel itself began to give. Some of our structural-shape reinforcement was latticed according to the common method; another type used horizontal ties at about the same distance apart; still another set was made with the steel reinforcement placed in the interior. Our results, so far as I have been able to study them, seem to show that we cannot expect

Mr. Talbot. entire unity of action between the steel and the concrete in columns of this type. It is of course easy to see, when one comes to make a design, that it will be quite difficult to carry the loads into these columns and get a fair distribution of load between the steel and the concrete.

Mr. Howard. **MR. J. E. HOWARD.**—Regarding the question of endurance of concrete to repeated stresses, tests at Watertown Arsenal were carried along lines which were intended to show the changes in the modulus of elasticity, or the apparent modulus of elasticity, as successive higher stresses were applied. Commonly, lower values of the modulus are found after higher stresses are applied and released, directing attention for the time to a given low range of stresses. Probably the modulus of elasticity was really unchanged, but on account of a partial disintegration of the concrete the intensity of the stresses locally was increased. Apparent reductions in the value of the modulus of elasticity occurred in the case of the leaner mixtures, neat cement not being affected by the application of higher stresses. In order to secure durability in concrete, excessive strains should be prevented, and a truly efficient method of reinforcement will tend toward accomplishing such a result. As an economic question, the use of richer mixtures commends itself, since the liberal use of Portland cement itself contributes greatly toward stiffening concrete used under compressive stresses.

Mr. Woolson. **MR. I. H. WOOLSON.**—I have been making some tests this winter and hope to report a little later on a large number of columns of a peculiar type being used in New York City for cheap building construction, such as tenement houses, and also for the six-story apartment houses, so called. The material used in these columns is ordinary scrap pipe filled with concrete. I call it scrap pipe, because as a matter of fact it usually is scrap pipe. They buy old pipe or tubing of any kind from any source, fill it up with concrete, and use it in place of cast iron columns. We have tested some sixty or more of these columns of different sizes this winter, but I have not yet had time to get the data in shape for presentation. It is rather an interesting type of construction which probably will have considerable use, because it really does make a very strong cheap column.

FURTHER TESTS OF REINFORCED CONCRETE BEAMS UNDER OFT-REPEATED LOADING.

BY H. C. BERRY.

Six additional beams, making eleven in all, have been tested under repeated loading during the past year in the laboratory of the Civil Engineering Department of the University of Pennsylvania. The concrete, apparatus, and methods of testing were described in a paper before this Society last year. The later series of beams had a less per cent. of reinforcement in order to more nearly approach the "ideal ratio" for a stress of 16,000 lbs. per sq. in. in the steel and 500 lbs. per sq. in. in the concrete.

The following tables are continuations of the corresponding tables published in the previous report. (See Proceedings, Vol. VIII, pp. 454-468.)

TABLE I.—TESTS OF STEEL IN BEAMS.

Bar.	Yield Point, lbs. per sq. in.	Ultimate Strength, lbs. per sq. in.	Elongation in 8 ins., per cent.	Reduction of Area, per cent.
Plain.....	35,600	52,000	30	60
Corrugated	53,400	88,800	13	13
Diamond.....	57,500	92,000	15	19
General Fireproofing Co.	32,000	45,000	25	44

TABLE II.—TESTS OF SIX-INCH CUBES.

Concrete from Beam No.	No. of Cubes.	Age, weeks.	Average Ultimate Strength, lbs. per sq. in.	Extreme Variation, per cent.
11	4	15	3,200	25
12	2	15	2,600	10
14	3	12	3,300	30
15	3	12	2,800	25
16	3	8	2,500	10
17	3	8	2,200	25
19	3	28	5,100	9

TABLE III.—SUMMARY OF TESTS SHOWING MAXIMUM LOADS AND DEFLECTIONS.

Beam No.	Reinforcement.	Repetition Tests.				Ultimate Load, lbs.	Maximum Deflection, ins.
		Total Load, lbs.	Unit Stress, lbs. per sq. in.		Number of Applications.		
			Steel.	Concrete.			
8	3 bars, $\frac{1}{2}$ in. sq.	4,170	15,800	640	1,400,000	10,600	0.5
11	3 plain rods, $\frac{1}{2}$ in. diam.					9,500	0.3
12	3 " " " " " " " " " " " "	3,270	15,700	500	1,600,000	8,000	0.4
14	3 plain rods, $\frac{1}{2}$ in. sq. . . .	4,170	15,800	640	920,000	9,500	0.3
15	3 " " " " " " " " " " " "					12,000	0.5
16	4 Cor. bars, $\frac{3}{8}$ in. diam. . . .	3,270	16,500	500	960,000	9,000	0.5
17	4 " " " " " " " " " " " "					10,800	0.6
18	3 Diam. bars, $\frac{1}{2}$ in. diam. |	3,270	20,000	640	1,200,000	13,600	0.5
19	2 General Fireproofing Co.'s $\frac{3}{8}$ -in. bars . . . . . |	3,270	16,800	500	1,800,000	12,500	0.5

Beam No. 8 was cracked on the compression side in removing from the apparatus, but on turning it over and setting in a testing machine it withstood a load of 10,600 lbs. applied at the third points of a 12-ft. span.

TABLE IV.—RELATION OF REPEATED STRESS TO INCREASE IN SET.

Beam No.	Stress Repeated in the Concrete.	Increase in Set per 100,000 Repetitions.
8	640	0.0000138
12	500	070
14	640	242
16	500	145
18	640	176
19	640	152

The results of these further tests lead to the conclusions given in the report of last year. They show that one and three quarter million applications of loads causing high working stresses in a reinforced concrete beam, do not materially affect the ultimate strength, the maximum deflection, the bond, the position of the neutral axis, nor the amount of the ultimate deformation in the concrete.

SOME TESTS OF BOND OF STEEL BARS EMBEDDED IN CONCRETE BY THREE METHODS.

BY H. C. BERRY.

Most tests of bond have been made by pulling a bar of steel out of a cylindrical block of concrete. Another method is to push the bar out of the block. Neither of these approximate the conditions existing in a reinforced concrete beam, for the design of which the results are desired. By the first method the concrete is in compression and the steel in tension at the time of failure; by the second, both are in compression. In the case of a loaded beam, however, both materials are in tension. It has been found that the bond between the concrete and the steel is very much less under these conditions than is indicated by the pull or thrust tests. This may be accounted for in part by the effect of the lateral deformation of the two materials under axial stress. This deformation would tend to make the concrete grip the steel when in compression and separate from it when in tension.

A practical objection to the use of the results based on pull-out and push-out tests as a safe guide in the design of beams is the method of molding the test specimen as usually made, in comparison with the method of casting a beam. It is usual in making a specimen to set the steel vertical and ram the concrete around it, while in casting a beam the steel is laid horizontal and the concrete rammed on the upper side only. The contact on the lower side is often imperfect; especially is this true for those types of deformed bars that have depressions in the surface which may occur on the lower side and not be filled with ordinary care in ramming.

A third method of making bond tests was described last year by Mr. Withey in a paper before this Society, Vol. VIII of the Proceedings, pp. 469-479. It consists essentially of a bending test on a small reinforced concrete beam in which a part of the length of the rod the bond of which is to be determined, is left exposed to allow the attachment of an extensometer. When the beam is loaded the elongation of the rod is measured and the pull

on it computed at the time of bond failure. The results by this method were from one-third to two-thirds of the values obtained from cylinder tests, all other conditions being the same.

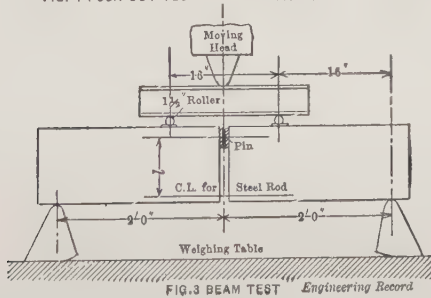
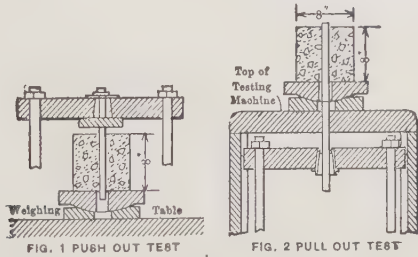
The tests herewith described were undertaken under the direction of the author by Mr. E. B. Callow and Mr. A. H. Moorshead, to whom acknowledgment is hereby made, as a senior thesis in the Department of Civil Engineering, University of Pennsylvania. The purpose was to compare the results obtained by the three methods, and to try out a modification of the third method by which it was desired to avoid the use of the extensometer and make possible the use of smaller specimens and greater rapidity in testing. This modification consisted in dividing the beam transversely at the middle by a 1-in. board at the time of molding, and in the use of a hinge when testing. The hinge was placed near the top of the opening left on the removal of the board and served to fix the position of the compressive force.

The materials used in making the concrete were Giant Portland cement, furnished by the American Cement Company, bar sand, and trap rock $1\frac{1}{2}$ -in. crusher run, purchased in the Philadelphia markets. A 1:2:4 mixture based on loose measurement was used. The cement passed the standard specifications of this Society; the tensile strength neat at 7 days was 500, and at 28 days 600 lbs. per sq. in. The sand was clean and fine; all passed a No. 10 sieve and 40 per cent. passed a No. 50 sieve. About 15 per cent. of the stone passed a $\frac{1}{4}$ -in. sieve. The weight of the sand and stone per cubic foot was carefully determined and the quantities for the different batches were weighed out instead of making volumetric measurements each time. Only two sizes of steel bars were used, $\frac{3}{4}$ -in. round and $\frac{3}{4}$ -in. square. The embedment was small enough that the elastic limit was not developed in any test.

The usual procedure in mixing the concrete was to spread the required weight of sand over the cement and turn them together until the mixture was of uniform color. Water was then added and the mortar well mixed. The required weight of stone, which had been previously dampened, was added by throwing alternate shovelfuls together. It was then turned four times. Water equal to about 20 per cent. of the combined weight of the

cement and sand was used, although the quantity varied somewhat, the appearance of the concrete being the criterion of the amount needed rather than a pre-determined percentage.

Medium consistency was used for the greater number of specimens. The concrete was sufficiently wet that water would rise to the surface on light tamping when placing it in 4-in. layers. A set of triplicate specimens was made with concrete of dry consistency, and another with concrete of very wet consistency. The dry was granular after thorough mixing and moisture could be brought to the surface only by thorough tamping. The wet con-



crete was so wet that it would flow when spread on the floor and could be stirred into place when put into the molds. Six-inch cubes were made from each kind of concrete and from nearly all the batches.

The specimens are shown in position for testing in Figs. 1,* 2, and 3. The cylinders were 8 ins. in diameter and 8 ins. high, with a steel rod 18 ins. long through the center of those for the pull-out tests, and one 9 ins. long for the push-out tests. A special

* Acknowledgment is made to the *Engineering Record* for the cuts used in this paper.—ED.

jig was arranged to hold the rods vertical during molding so as to avoid bending. The spherical compression block was of further assistance in obtaining axial pull. The cylinders were stored in damp sawdust and tested at 28 days. The specimens for the test in bending were 4 ft. 6 ins. long and 8 by 11 ins. in section. The center line of the steel was 1 in. from the bottom of the concrete. The steel extended about 8 ins. to either side of the transverse division of the beam at the middle. The wooden partition was left in position until the time of testing and removed when the hinge was placed. The beams were stored in air at about 70° F. and tested at 28 days.

The 6-in. cubes were stored in damp sawdust and tested at 28 days. The ultimate strength for those from the dry consistency was 3,520 lbs. per sq. in., based on 6 tests. These received a thorough tamping when molded. Those from medium consistency gave 2,650 lbs. per sq. in., as an average from 12 tests, and the wet ones 2,000 lbs. per sq. in., also averaged from 12 tests.

The mounting for the pull-out test is shown in Fig. 2. In the early tests the short projection of the rod was covered with plaster of Paris, which was trimmed down to the surface of the steel so that the edge of the latter would appear as a fine line. During the application of the load this line was watched and the reading taken when it was appreciably widened. After a few tests it was found that this occurred at the maximum load, when there was a marked "drop of the beam." Throughout the greater number of the tests the load as noted by the drop of the beam was taken as the bond strength.

The arrangement for making a beam test is shown in Fig. 3. The beam was loaded at two points symmetrically placed about the middle of the span, giving uniform bending moment throughout the middle part of the beam. Short reinforcing rods, bent up at the ends of the beam and extending into the concrete along the test bar, served to distribute the stress to the specimen and prevent failure of the beam in diagonal tension. The accuracy of the determination of the bond from a test arranged in this manner depends on the precision of the measurements of the lever arm of the pull in the steel about the center of the hinge, and the horizontal distance between the line of action of the load and the reaction on each side. To expedite setting up, a special frame

or jig was devised with notches for the upper rollers and pointers for placing the supports. The jig was clamped to the side of the beam and the setting quickly made. Another simple frame with a slide on the bottom was made for quick measurements of the lever arm of the steel.

The hinge was made of two steel bars $2\frac{1}{2}$ by $\frac{3}{8}$ by 9 ins., with a groove milled to the slope of a standard taper pin extending from each end toward the center. On the removal of the upper part of the board the sides of the hinge were set in place and the pins driven to a tight bearing. After measurement of the lever

TABLE I.—BOND BETWEEN CONCRETE AND STEEL.
(In pounds per square inch of surface in contact.)

Method of Testing.	Consistency.	Square Bars.	No. of Tests.	Round Bars.	No. of Tests.	Average of Both.	Ultimate Strength of Cubes.
Pull-out Tests	Dry	694	3	741	3	718	3,500
	Medium	589	10	638	10	614	2,650
	Wet	591	3	475	3	533	2,000
						—618	
Push-out Tests	Dry	672	3	469	3	570	3,500
	Medium	444	9	666	6	453	2,650
	Wet	498	3	531	3	514	2,000
						—497	
Beam Tests	Dry	140	3	230	3	185	3,500
	Medium	268	7	280	7	274	2,650
	Wet	184	3	240	3	212	2,000
						—237	

arm the load was applied at lowest speed. The deflection was noted for increments of 1,000 lbs., and if it became greater than about 0.07 in. the load was released, the pins driven tighter, and the test begun again. In this way undue bending of the specimen was avoided.

Five beams were tested with sufficient length of the steel exposed to permit the application of the Ewing extensometer. This made it possible to check the pull in the bar by a measurement of the elongations. The results checked with those based on the load and measurements of the lever arms within less than $2\frac{1}{2}$ per cent. This is less than the variation to be expected among the specimens of a set taken from the same batch of concrete,

and shows that with ordinary care the method is sufficiently accurate and possesses the advantage of smaller specimens and greater speed in testing without any risk to delicate apparatus from unexpected failures.

Two beams with deformed bars were tested, but they failed by pulling out the concrete at the bottom of the beam rather than by failure in bond.

From Table I it is seen that the average value of the bond, including the different consistencies and both forms of rods, is

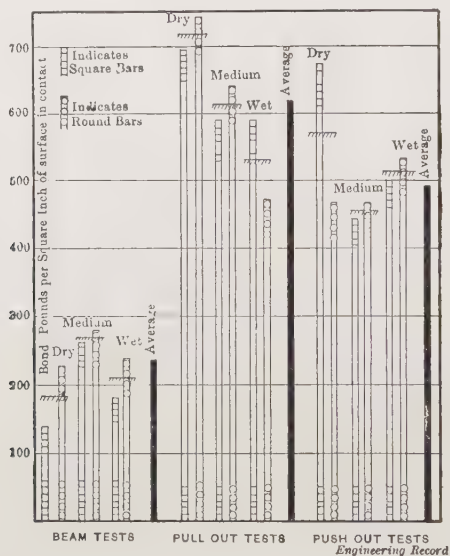


FIG. 4.

237 lbs. per sq. in., while for the pull-out tests it is 618 lbs. per sq. in., about 2.6 times as much; and for the push-out tests it is 497 lbs. per sq. in. of surface in contact, or about 2.3 times that for beams. It is also to be noted that the round bars gave the higher average for 7 of the 9 series. The results are shown graphically in Fig. 4.

From these values it is evident, as was shown in the paper referred to above, that the maximum value of the bond between concrete and plain steel in reinforced concrete beams is between 200 and 250 lbs. per sq. in., and that this value instead of the

higher values usually quoted should be taken for guidance in reinforced concrete design.

From these tests it is also evident that pull-out and push-out tests give approximately the same results. The modified form of the specimen for beam tests gives the same values of the bond as that requiring the use of the extensometer and with as great a degree of accuracy, this depending only on the precision with which the lever arms are measured, and makes possible much greater speed in testing, which may be increased still further if the hinge be replaced by two or more short rods set in a plane near the top of the beam at the time of molding. This would avoid any loss of time in setting the hinge, and make the beams more rigid and less liable to accident in handling, but would make the position of the center of the compressive force slightly uncertain.

NOTES ON THE BEARING VALUE OF RODS EMBEDDED IN CONCRETE.

BY ROBERT A. CUMMINGS.

If a load is so placed that a reinforced concrete member is subjected to vertical shear, we reason that the concrete and the metal reinforcement act together. Our structures are frequently designed in accordance with this assumption.

Three or four years ago, during a convention of this Society, the writer brought to the attention of a party of engineers the fallacy of assuming that two such materials act together in shear. Since that time the subject has not been publicly discussed. Perhaps this may be accounted for by the fact that in the large number of published tests on reinforced concrete beams, failure by vertical shear has been the exception; and wherever beams have thus failed, the failure has been attributed to insufficient sectional area of concrete.

The common practice in determining the end shear of beams is to allow so much for the concrete and to make up any deficiency with steel at so many thousand pounds per square inch of cross sectional area. The basis for such practice cannot be explained. While it is quite proper to consider the area of concrete as available for shearing, the steel should not be included. It would be more appropriate to regard the relation of the concrete to the steel as bearing on the rods, if they are sufficiently anchored and suitably placed.

Analogous to the above combination of concrete and rods is that of bolts embedded in concrete for attaching brackets to support a load. Neglecting friction, the load will ultimately reach the concrete through the bearing of the embedded bolts. What then will be the bearing value of bolts embedded in concrete in resisting a force acting at right angles to the axis of the bolt? This will naturally depend on two things, the size and rigidity of the bolt, and the density of the concrete.

This question recently arose in the writer's practice in connection with methods for supporting the centering for concrete

arches; also for supporting steel brackets on concrete columns by means of embedded bolts projecting from the concrete. These bolts were in single shear and in proper proportion. The bearing value of the concrete to receive the load from the bolts was unknown.

The object of the following tests, which were conducted under direction of the writer by E. B. McCready of the Lehigh Valley Testing Laboratory, Allentown, Pa., was to obtain the bearing values for such bolts; and these notes have been presented to direct the attention of experimenters who are interested in the subject, and possess the necessary time and facilities to extend and complete the investigations. Such work cannot be expected of an active practicing engineer.

Tests were made on $\frac{3}{4}$ -in. square and $\frac{3}{4}$ -in. round, straight steel rods embedded in a short column of concrete, with the ends projecting equally about 3 ins. on either side (Fig. 2). When the specimen was placed in the testing machine, the projecting rods were evenly supported on cast iron bearings which were held in close contact with the concrete. The rods were thus tested for double shear. Specimens were made to be tested at 30, 60, and 90 days. In all 24 specimens were made, 2 each for each kind of rod and for each period, being made from both 1:2:4 and 1:3:6 mixtures. It was not convenient to test the first lot at 30 days, so they were tested at 35 days.

MATERIALS.

The concrete for these tests was made from bank sand and gravel screened from the sand. The sand was fairly clean and well graded, and of the following composition:

Passing the 200-mesh sieve.....	2.0	per cent.
“ “ 100 “ “	3.2	“ “
“ “ 80 “ “	4.0	“ “
“ “ 50 “ “	8.4	“ “
“ “ 40 “ “	13.6	“ “
“ “ 30 “ “	22.2	“ “
“ “ 20 “ “	43.6	“ “
“ “ 10 “ “	77.4	“ “
“ “ 4 “ “	100.0	“ “

The percentage of voids, determined by shaking down in water, was 32.3. The composition of the gravel was as follows:

Passing the $\frac{1}{4}$ -in. mesh.....	2.1	per cent.
" " $\frac{1}{2}$ " "	30.2	" "
" " $\frac{3}{4}$ " "	56.5	" "
" " 1 " "	91.8	" "
" " 2 " "	100.0	" "

A standard brand of Portland cement was used:

TENSILE STRENGTH.

<i>Age.</i>	<i>Neat Cement.</i>	<i>Strength.</i>
24 hours.....		472 lbs.
7 days.....		903 "
28 days.....		832 "

With Standard Quartz.

7 days.....	234 lbs.
28 days.....	299 "

TIME OF SET.

<i>Initial</i>	3 hours, 20 minutes.
<i>Final</i>	7 " 15 "

FINENESS.

Passing the 100-mesh sieve	93.2	per cent.
" " 200 " "	77.6	" "

Compression cylinders 8 ins. diameter and 16 ins. high were made up in the proportion 1:2:4 and 1:3:6, three for each test at each period (Fig. 2). Those tested at 30 days broke as follows:

1 : 2 : 4	1 : 3 : 6
1932 lbs. per sq. in.	603 lbs. per sq. in.
1721 " " " "	721 " " " "
2127 " " " "	909 " " " "
1927 " " " "	744 " " " "

METHOD OF TESTING.

Bearing test specimens were square columns with a 10 by 10-in. base and 24 ins. high. As originally made, each column had a 6-in. footing on one side to give stability to the block in testing, because it was first planned to apply pressure at one point only (see Fig. 2). The specimens were made in a wooden form which had a $\frac{3}{4}$ -in. square hole cut through two opposite sides, one of the sides being that on which the footing projected and which we will call the "front" (see Figs. 4 and 5); and exactly the same

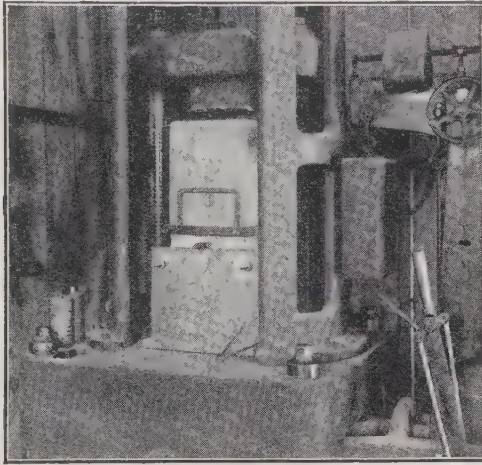


FIG. 1.—Method of Testing.

distance from the bottom, just midway between the upper surface of the footing and the top of the column. The rod to be embedded was put through these holes and projected equally from front and back about 3 ins. This latter fact permitted a change in the original plan and the specimens were tested in double shear.

For this purpose two iron castings were made, $\frac{7}{8}$ in. in thickness and in vertical section like an inverted letter "T," the base of which was 5 ins. and the height 12 ins. These castings were 14 ins. long, and served as supports for the test specimens, the projecting rods bearing on either support. The supports were held close to the concrete by iron bolts extending through both

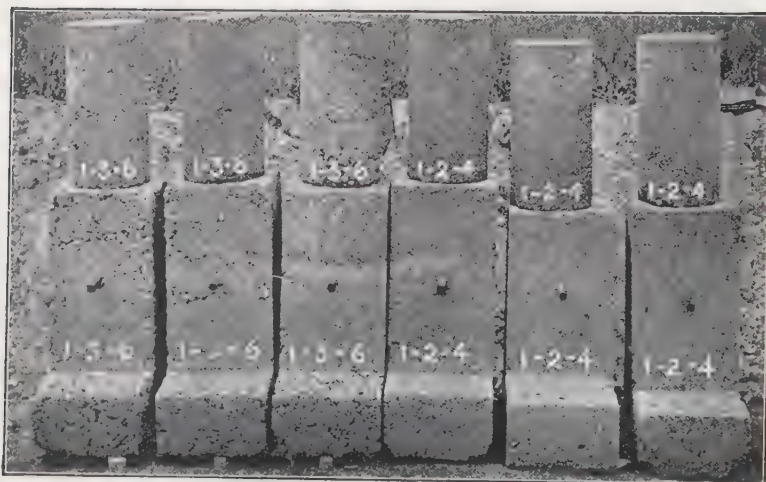
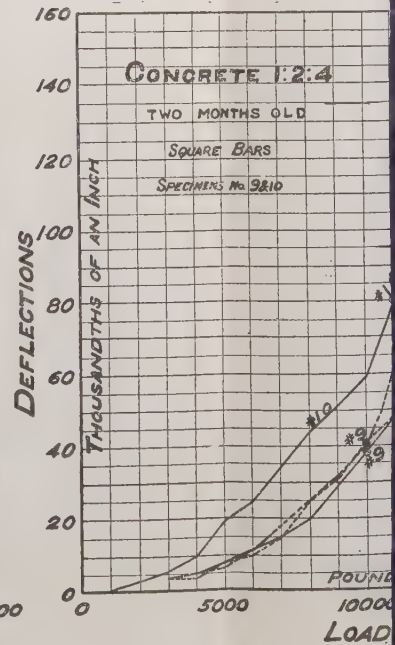
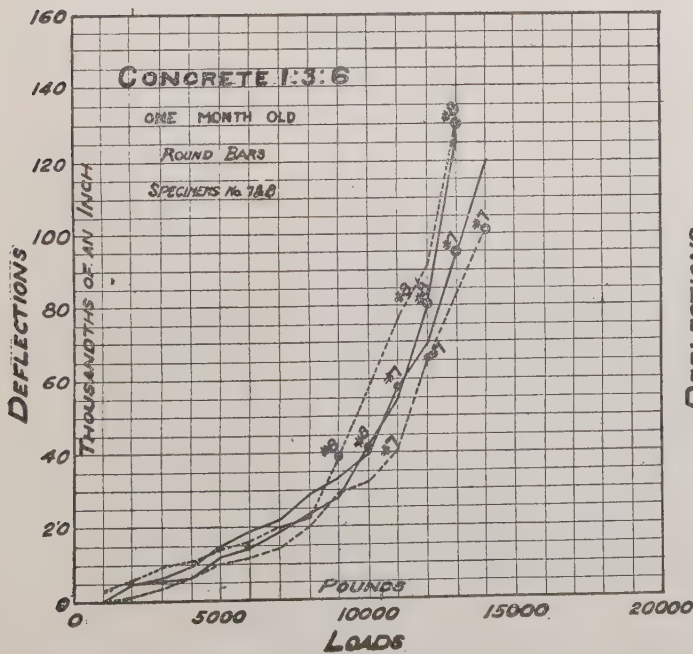
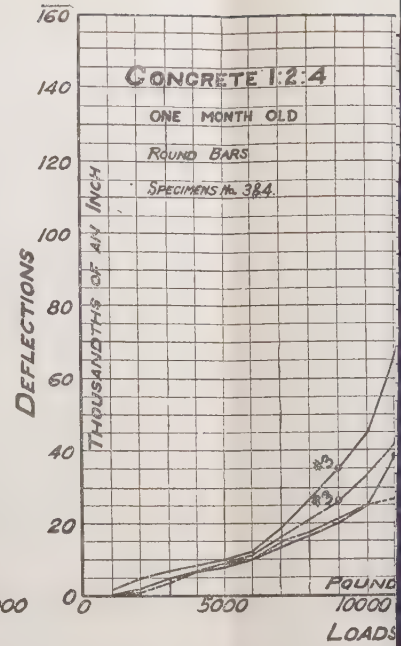
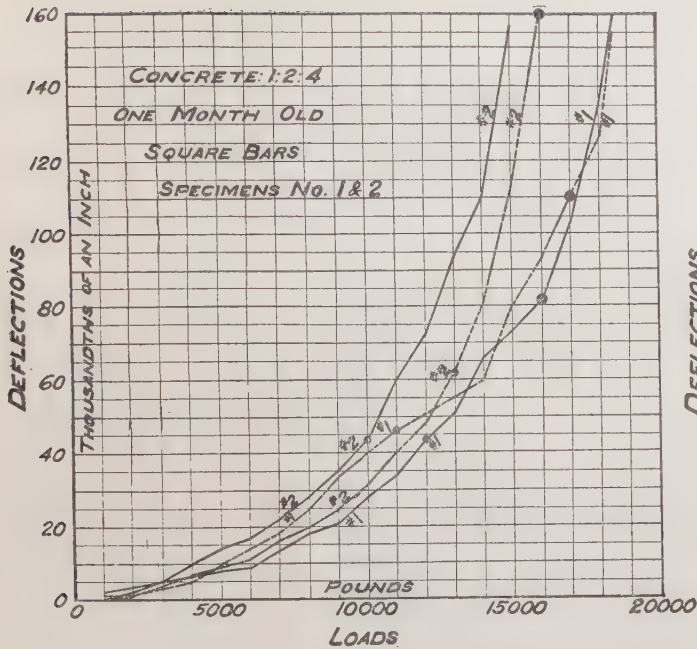


FIG. 2.—Compression Test Cylinders and Specimens before Test.



FIG. 3.—Specimen after Test, showing Concrete Removed and Bent Rods.



Bars: $\frac{3}{4}$ -in. squares and $\frac{3}{4}$ -in. rounds, as indicated.

— Front of rod.

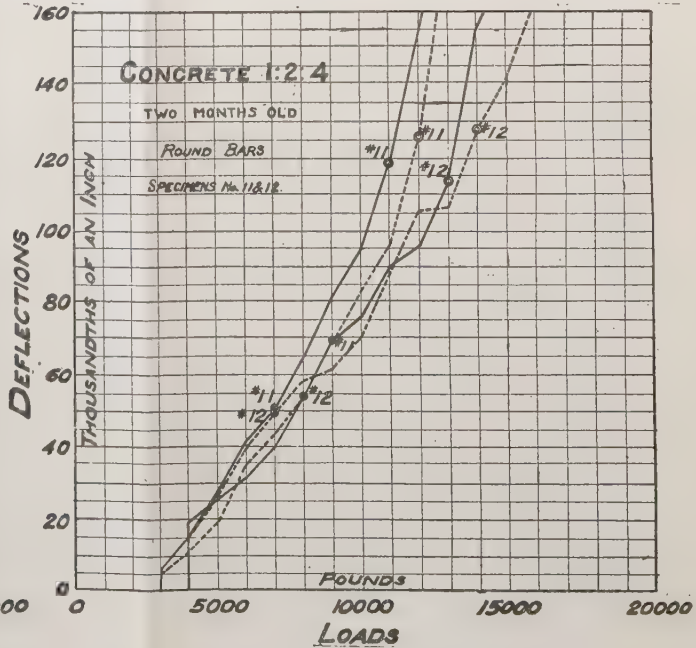
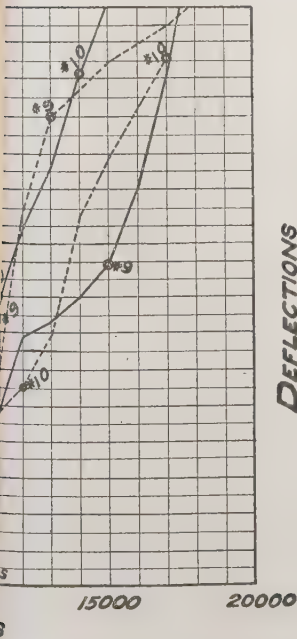
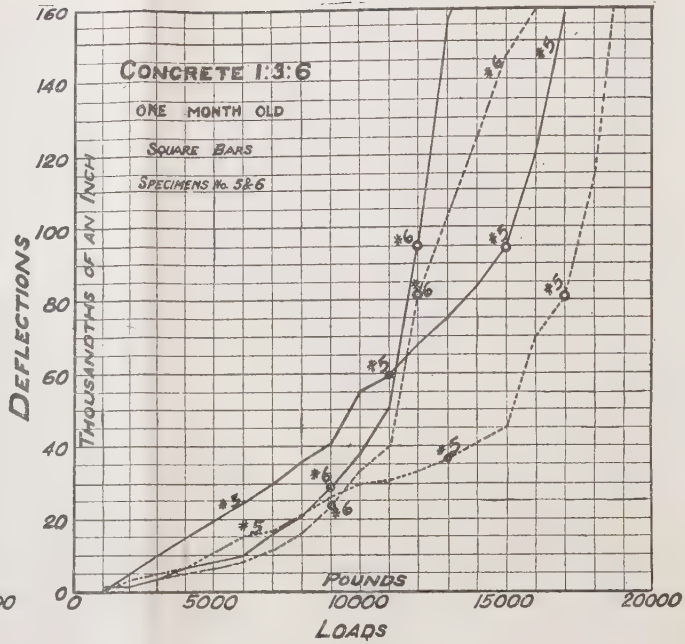
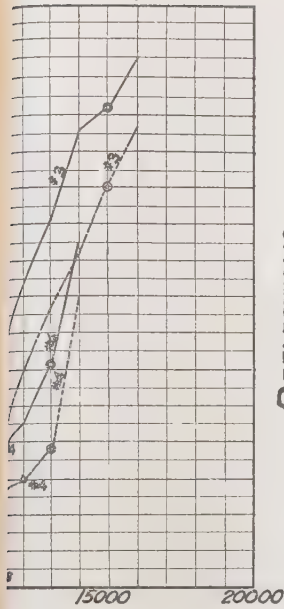
----- Back of rod.

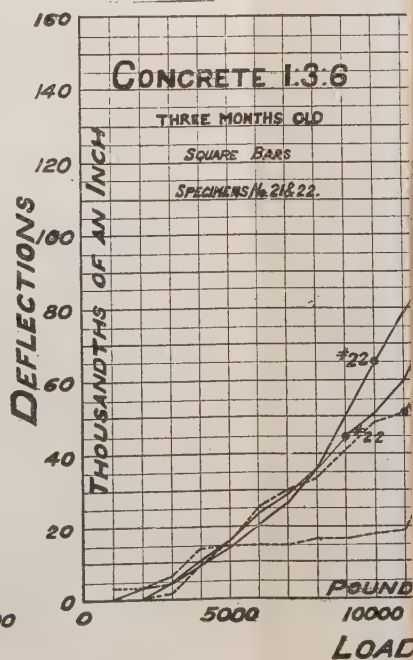
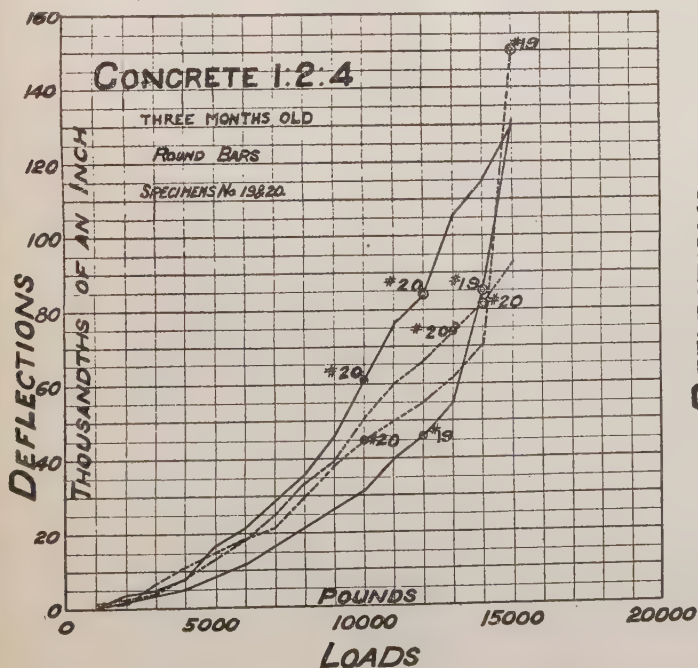
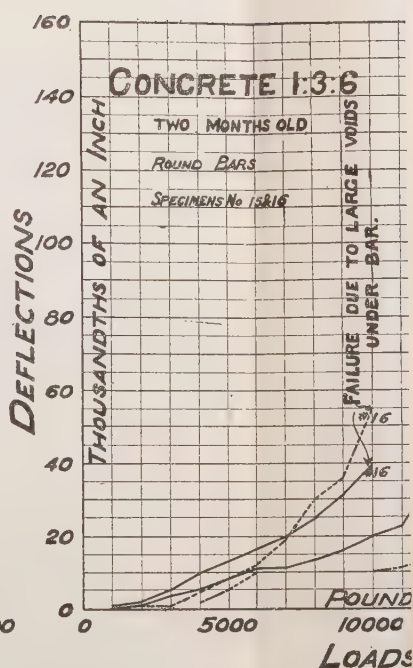
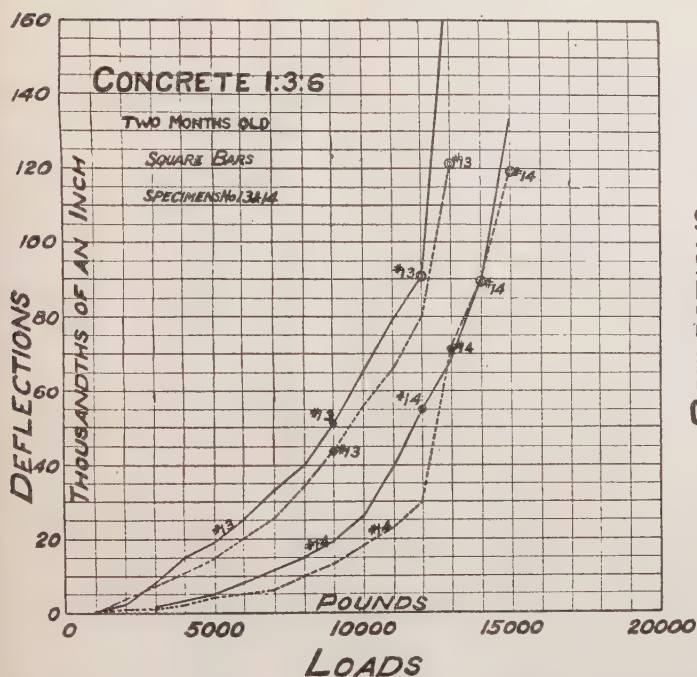
● Began to powder and chip off under bar.

○ Cracked and broke out.

NOTE.—Measurements taken until the bending bar refused to sustain further load long enough for measurement.

FIG. 4.





Bars: $\frac{3}{4}$ -in. squares and $\frac{1}{2}$ -in. rounds, as indicated.

— Front of rod.

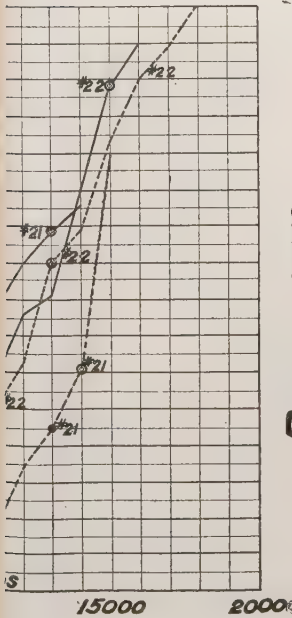
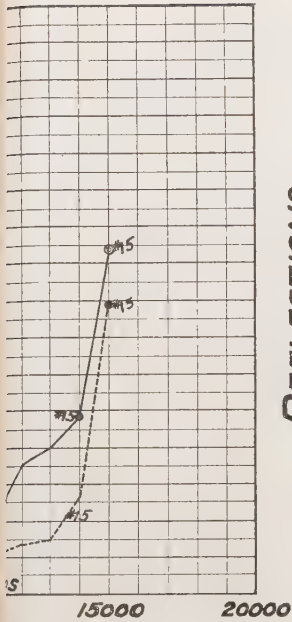
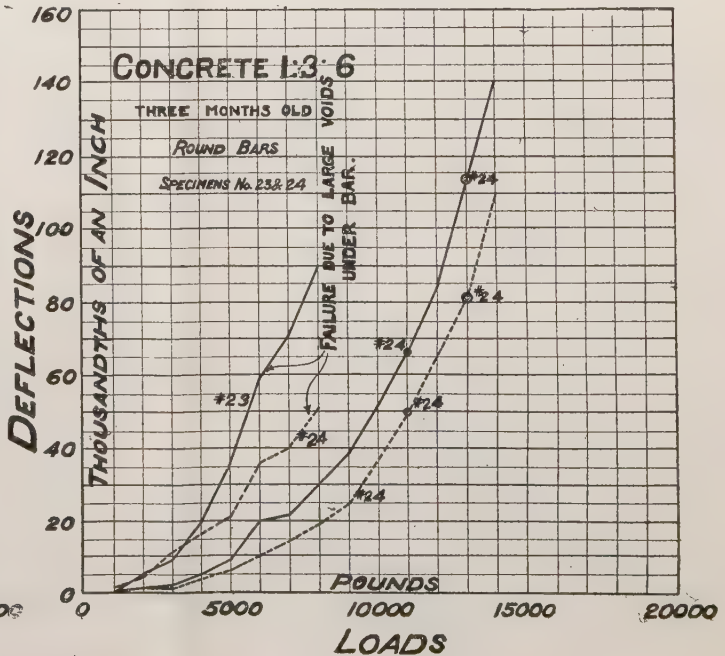
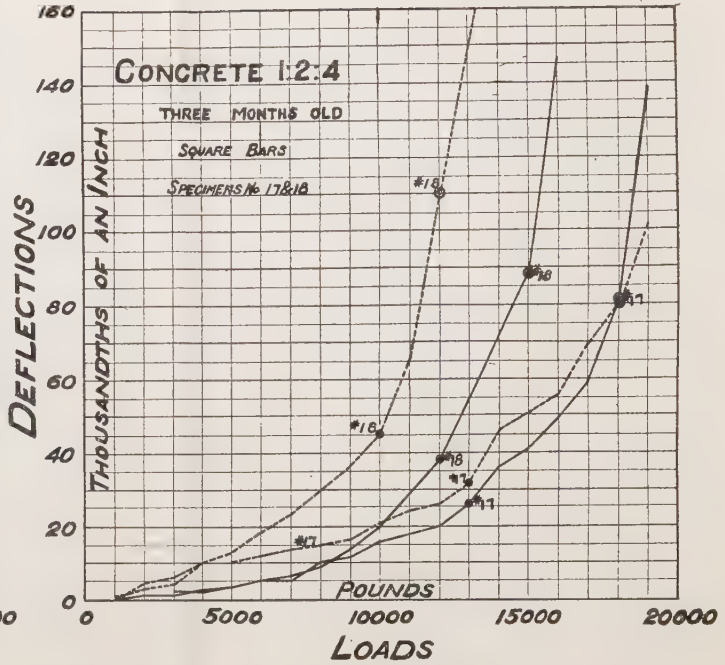
--- Back of rod.

● Began to powder and chip off under bar.

○ Cracked and broke out.

NOTE.—Measurements taken until the bending bar refused to sustain further load long enough for measurement.

FIG. 5.



castings, about $1\frac{1}{2}$ ins. from either edge and 2 ins. from the top. The bolts were threaded on each end so that the supporting plates could be drawn to contact with the concrete.

Pressure was applied through a $1\frac{1}{2}$ -in. round bar laid on top of the specimen at right angles to the direction of the embedded bar. The load was applied in increments of 1,000 lbs. each, careful measurements being taken and observations made after each loading to determine the deflection of the bar and note the condition of the concrete. Measurements were made with an inside micrometer and checked with an inside caliper and outside micrometer. Electrical contact was used.

Contact points were marked on the upper surface of the projecting bar, right against the surface of the concrete and on the under side of a specially designed iron frame (see Fig. 1)* attached to the concrete column by four pointed set-screws. This frame was attached at a height of about 1 in. above the projecting rod, in order to avoid, as far as possible, all error due to crushing or compression of the concrete. An extension above the frame was provided for the upper point of contact, which was 4 to 5 ins. above the rod.

DESCRIPTION OF THE TESTS.

Failure in each case was caused by the bending of the rod for about an inch in from the surface of the concrete, causing the latter to powder and crumble and finally scale off to a depth of $\frac{1}{4}$ to $\frac{1}{2}$ in. The surface area thus scaled off varied from $1\frac{1}{2}$ to 3 ins. in diameter, according to the nature of the aggregate at the surface at that point (see Fig. 3). When the rod began to bend and the scaling off of the concrete was noticed, the test was practically at an end, as the rod simply continued to bend and it was impossible to increase the loading. In those cases where several thousand pounds were added to the load after the breaking out of the concrete before complete failure occurred, the rod was supported by one or more large pebbles which had not broken out.

By referring to the diagrams, Figs. 4 and 5, Plates VII and VIII, it will be noticed that the curves are quite irregular. This

* Acknowledgment is made to the *Engineering Record* for the cuts of Figs. 1 and 2.
—ED.

irregularity may be due to variation in the density of the mixtures, the existence of voids in the leaner mixture, or local resistance caused by a large stone. In any event two specimens of the 1:3:6 mixture failed through the existence of voids under the rods. If therefore we find such voids in "prepared" specimens when the rods are fixed in the molds, there is special reason to avoid this liability in future practice.

The results of the tests on concrete 1 month old for both mixtures with rounds and squares show a bearing value practically equivalent to that of the same concrete when 3 months old. It will also be noted that the deflections for the same are nearly 20 per cent. less. Therefore it is not unreasonable to infer that this difference in results may be attributed to the influence of the rigidity of the rod, yet the bearing values or deflections between the rounds and squares are not so marked.

The results of the tests on specimens 2 months old are slightly inconsistent, those for the squares showing an inappreciable retrogression in bearing value although an increase in deflection, while those for the rounds show a considerable difference in bearing values with practically the same deflection.

These tests cannot be accepted as conclusive, but indicate a possible ultimate bearing value without deterioration to the concrete for $\frac{3}{4}$ -in. round and square rods, when located in a manner similar to that here described, of 5,500 lbs. for each projecting rod. These tests also suggest that the subject of the bearing value of rods embedded in concrete should be more fully investigated with reference to the effect of the size, shape, and rigidity of the rod, as well as the character of the concrete. No final conclusions can be drawn from a single series of tests. In fact, the whole subject of reinforced concrete is an undeveloped and fascinating field, and we are woefully in the dark as to internal stresses and the influence of variations in the position and amount of embedded reinforcement—witness the extraordinary variety of systems of reinforcement and the disagreement of authorities over all but simple stresses.

THE COMPRESSIVE STRENGTH OF CONCRETE PIERS AS AFFECTED BY VARYING BEARING AREAS.

BY EDGAR MARBURG.

Steel columns are frequently supported on concrete piers without cap stones. The sectional area of the pier is commonly about twice as large as that of the steel base. If the latter is properly designed with gusset plates of adequate stiffness the load, under faulty bedding, may be concentrated along the outer rim of the base. On the other hand if the steel bases are improperly designed, as is not infrequently the case, the intensity of the pressure may be much greater at the center than near the outer edges of the bearing plates. The latter condition may obviously arise also under improper bedding, irrespective of the design of the steel pedestals. In view of the paucity of experimental data relative to the strength of concrete piers under such extreme conditions of bearing on their upper faces, the writer drew up a program of tests of small concrete piers which was executed in the testing laboratory of the Department of Civil Engineering, University of Pennsylvania, as a thesis exercise by Mr. W. S. Lohr and Mr. A. H. Woerner under the immediate supervision of Mr. H. C. Berry, Assistant Professor of Materials of Construction. The results are considered of sufficient interest to warrant presentation in brief form.

The tests embraced forty-eight prisms 12 ins. square in four series of twelve specimens each, 12, 18, 24, and 30 ins. high, although it was expected that the variations in height would not affect the results materially. That anticipation was confirmed by the tests. Three prisms of each height were tested under each of the four bearing areas on the upper face shown in Fig. 1, namely, full bearing, half-bearing, quarter-bearing (solid), and quarter-bearing (hollow). On the lower face full bearing was provided in every case. The prisms were all tested at the age of 28 days.

Materials.—The concrete consisted of Giant Portland cement, Jersey bar sand, and $1\frac{1}{2}$ -in. crusher-run trap rock in the proportions of 1:2:4 by loose volume. The consistency was "medium-wet," the weight of water being about 21 per cent. of that of the cement and sand.

Mixing and Molding.—The concrete was mixed in eight batches, each of sufficient volume for six prisms and three 6-in. cubes, and, in one case, for six additional 8-in. cylinders, 16 ins. high. The concrete was placed in wooden molds in layers about 3 ins. thick and each layer was rammed with a $1\frac{1}{2}$ -in. square wooden rammer weighing about 5 lbs., the water being easily flushed to the surface. After 3 days the prisms were removed from the molds and allowed to season in damp saw-dust. To ensure true end faces, steel plates were placed in the bottom of

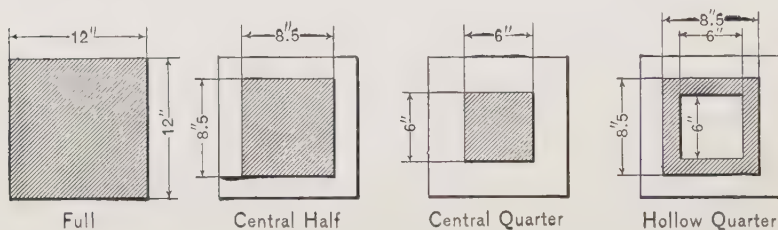


FIG. 1.

the molds, and the upper surfaces were finished with extraordinary care by means of a steel straight-edge guided by the edges of a steel yoke clamped to the top of the prisms and adjusted with the aid of a spirit level after the prisms had been placed on a leveled steel slab.

Testing.—The tests were made in a 600,000-lb. Olsen machine with a spherical compression block acting on the bearings on the upper face of the specimens. These bearings consisted of 1-in. planed steel plates, of the shapes and sizes shown in Fig. 1. Compressometer measurements were also made for determining the modulus of elasticity, but these will not be included in this report.

Results of Tests.—The twenty-four 6-in. cubes developed an ultimate strength ranging from 1,810 to 2,440 lbs. per sq. in., the average value being 2,070 lbs. The six 8-in. cylinders gave an ultimate strength ranging from 1,100 to 1,460 lbs. per sq. in.,

and a mean value of 1,300 lbs. Three 6-in. cubes made from the same mixture and tested at the same time as the cylinders exhibited an average crushing strength of 2,100 lbs. per sq. in.

The results of the tests of the prisms are shown in Table I. Each quantity represents the mean of three values. The individual results in each set gave as fair an agreement as is to be expected for such material. The ratio of the load producing the initial crack to the ultimate was, however, very variable, ranging from somewhat less than 50 to 100 per cent., the average ratio being 87 per cent. The average ratio is lowest, 78 per cent., for the full bearing, and highest, 95 per cent., for the solid quarter-bearing, as was to be expected.

The results are shown graphically in Fig. 2, each point representing the mean of three values,

TABLE I.

Top Bearing.	Height, ins.	Total Load.		Unit Load.		
		Initial Crack, lbs.	Ultimate, lbs.	Initial Crack, lbs. per sq. in.	Ultimate, lbs. per sq. in.	Bearing, lbs. per sq. in.
Full Bearing	12	149,600	243,530	1,040	1,690	1,690
	18	195,300	265,730	1,360	1,845	1,845
	24	192,000	254,470	1,330	1,770	1,770
	30	280,700	285,730	1,950	1,980	1,980
	Average			1,420	1,820	1,820
Half Bearing	12	166,800	190,970	1,160	1,320	2,640
	18	134,000	164,670	930	1,145	2,290
	24	167,000	177,290	1,160	1,235	2,470
	30	164,800	174,330	1,140	1,210	2,420
	Average			1,100	1,230	2,460
Quarter Bearing (Solid)	12	93,300	110,400	650	765	3,060
	18	115,400	120,500	800	835	3,340
	24	140,800	143,550	980	995	3,980
	30	147,600	153,070	1,030	1,060	4,240
	Average			860	910	3,640
Quarter Bearing (Hollow)	12	108,000	155,030	750	1,075	4,300
	18	153,900	168,540	1,070	1,170	4,680
	24	150,000	170,500	1,040	1,185	4,740
	30	183,700	185,470	1,280	1,290	5,160
	Average			1,030	1,180	4,720

Conclusions.—1. The results are not visibly affected by variations in the ratio of height to side within the limits, 1 to 2.5, embraced in these tests.

Designating the full bearing, the half-bearing, the quarter-bearing (solid) and the quarter-bearing (hollow) as Nos. 1, 2, 3, and 4 respectively:

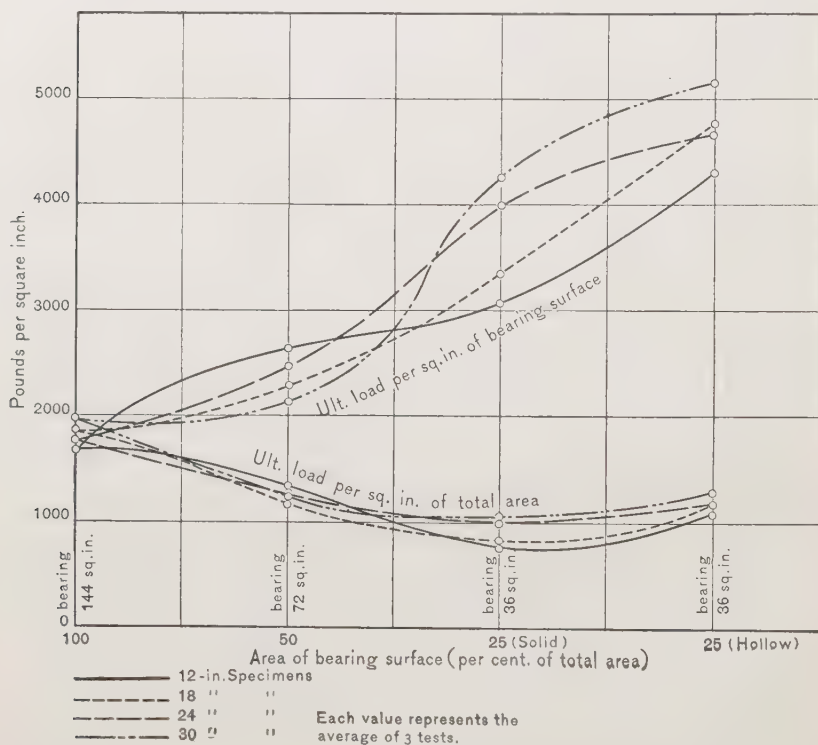


FIG. 2.

2. The ultimate load per square inch of bearing surface is twice as great for No. 3 as for No. 1, and for No. 4 as for No. 2, the continued ratio of this maximum bearing intensity being approximately 3 : 4 : 6 : 8 for Nos. 1, 2, 3, and 4 respectively.

3. The ultimate load per square inch of total sectional area of prism is half as great for No. 3 as for No. 1, and about two-thirds as great for Nos. 2 and 4 as for No. 1, the continued ratio being approximately 6 : 4 : 3 : 4 for Nos. 1, 2, 3, and 4 respectively.

Perhaps the most important fact indicated by these tests is that the hollow bearing, No. 4, having an area of only one-fourth the sectional area of the prism, develops as high a crushing load (within 4 per cent.) as bearing No. 2 possessing twice as great an area of contact.

Observations on the manner of failure developed some interesting features which cannot be satisfactorily presented in a brief description without the reproduction of numerous photographs.

CONCRETE REINFORCED BY NAILS.

BY LEON S. MOISSEIFF.

Concrete reinforced by metal to sustain tensile stresses produced by flexure has been explored most fully in all its possibilities during the last twenty years. The strength of reinforced concrete in compression, both direct and due to flexure, has also received much attention more recently. These researches have not only furnished the engineering world with a good working knowledge of reinforced concrete, but at the same time have widened our horizon in the field of the resistance of materials. By the very character of concrete, which has a tensile and shearing resistance many times lower than its compressive strength, and on account of the possibility of reinforcing this material in one direction or another, it lends itself most readily to experimental research in several directions, such as the effect of lateral restraint or enhanced shearing resistance. It is true that concrete is not a sufficiently homogeneous material to afford exact experimental data which could be utilized in comparative studies to a nicety. But for structural materials and engineering purposes it is important to obtain even gross experimental results, and in many cases such information is sufficient.

Such gross results will be presented herewith on the compressive resistance of concrete cubes reinforced by wire nails. The writer claims a fairly extensive acquaintance with the literature of reinforced concrete, and he does not recollect having encountered mention of tests made on concrete reinforced in this manner.

That no attention was paid to the means of increasing the compressive resistance of concrete by the embedding of wire nails, cut wire, nuts, etc., is not surprising, because it is, on its face, very uneconomical and does not promise commercial success. Wherever such means of reinforcing may have occasionally been used, it probably has not been considered important enough to make a series of tests which would be worth while recording. The great compressive strength that can be developed in concrete reinforced in this way must have remained entirely undisclosed.

The occasion which led to the series of tests described in this paper arose from conditions requiring the use of an initially plastic material which should fill certain spaces, harden to an imperishable state, and develop, within a comparatively short time, great compressive resistance without sustaining much deformation. Thus it was practical need that prompted investigation in this case.

Some time ago it developed that it was advisable to fill the compartments of a large steel casting with a material as described above. This casting formed a pedestal of an important bridge being constructed by the Department of Bridges of the City of New York. Mr. C. M. Ingersoll, Consulting Engineer, then Chief Engineer, suggested the use of concrete reinforced by wire nails or cut wire and ordered tests of this material to be made. The results of these tests were so satisfactory that concrete reinforced by wire nails was adopted for the filling of the casting.

Altogether 75 test cubes were made, 60 of which were broken, the remaining 15 being left for age tests. Those broken consisted of 57 specimens reinforced by wire nails, 1 by cut wire, and 2 by scrap iron consisting of nuts, nails, clippings, etc. Of those reinforced by wire nails 55 were 6-in., and 2 were 12-in. cubes, the latter being the only 12-in. cubes tested.

Several standard brands of Portland cement were used in the making of the cubes, but no separation of the results with respect to the brands has been made in this paper.

The cubes were made of a cement and sand mortar and standard eight-penny wire nails, 0.1 in. diameter and $2\frac{1}{2}$ ins. long. In all but 2 cubes the proportions of the mortar were 1 to 2. The aggregates were proportioned by weight as follows: 4 lbs. 2 oz. of Portland cement, 8 lbs. 4 oz. of sand, and 11 lbs. of wire nails.

The cement and sand were first mixed dry and about 12 per cent. of water was added, making a fairly stiff mortar. The nails, having previously been slightly wetted, were then added and mixed with a trowel in the usual way, the same as for broken stone concrete. The concrete was then placed in the forms in layers of about one inch and tamped. The upper surface was finished with 1 to 2 mortar. The forms were removed in about 48 hours. They were then kept in the air and wetted daily by

sprinkling until used. The weight of the concrete thus made was 196 lbs. per cu. ft.

The cubes looked smooth on the outside the same as plain concrete cubes, except that light brown spots, like small-pox marks, sometimes showed discoloration of the concrete by the embedded nails wherever the latter were exposed.

Table I contains the results of all the tests tabulated as to age of specimens, and the minimum, maximum, and average resistances of each group. As seen from the table there are 12 such groups, varying in age from 1 week to 18 months.

TABLE I.—CRUSHING STRENGTH OF SIX-INCH CUBES.
Pounds per square inch.

	7 Days.	1 Month.	1½ Months.	2 Months.	2½ Months.*	3 Months.	7½ Months.†	8 Months.‡	1 Year.	13 Months.§	15 Months.	18 Months.
Except where noted, the proportions are: 4 lbs. 2 oz. of Cement. 8 " 4 " " Sand. 11 " Wire Nails.	1 2,890	5,780	7,220	6,220	6,110	9,450	13,890	15,300	10,550	14,450	17,800	13,050
2 3,000	5,720	5,610	6,450	.....	.....	8,340	.....	15,300	11,100	8,900	16,670	.....
3 3,050	6,000	7,560	6,550	.....	.....	8,340	.....	.....	10,550	.....	.....	.....
4 3,165	5,280	6,280	6,670	.....	.....	.....	.....	.....	9,440	.....	.....	.....
5 2,890	5,550	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
6 3,050	6,280	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
7 2,770	5,280	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
8 3,000	4,500	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9 3,050	5,890	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10 3,000	7,000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11 2,890	5,550	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12 3,050	5,000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
13 3,330	8,340	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
14 3,050	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
15 2,770	5,550	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
16 2,890	5,550	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
17 3,330	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Maximum	3,330	8,340	7,560	6,670	6,110	9,450	13,890	15,300	11,100	14,450	17,800	13,050
Minimum	2,770	4,500	5,610	6,220	.....	8,340	.....	15,300	9,440	8,900	16,670	.....
Average	3,010	5,818	6,668	6,473	.....	8,710	.....	15,300	10,410	11,675	17,235	.....

SPECIAL SIX-INCH CUBES.

1. Cut wire, $\frac{1}{8}$ in. diam., $1\frac{1}{2}$ ins. long, filled with 1:2 grout,
7 days = 1,945 lbs. per sq. in.
2. Scrap iron (nuts, nails, clippings, etc.), filled with 1:2 grout,
7 days = 2,221 lbs. per sq. in.
3. Scrap iron (nuts, nails, clippings, etc.), filled with 1:2 grout,
28 days = 3,050 lbs. per sq. in.

* Nails laid in courses.

† 1:2 and 88 lbs. wire nails; same proportion as 6-in. cubes

‡ 12-in. cubes; 1:2 and 110 lbs. wire nails.

§ 1:1½ and 11 lbs. wire nails.

The tests were made in an hydraulic press of 350 tons capacity and the pressure was read off a pressure dial. The accuracy of the machine was within 3 per cent. In the case of the 12-in. cubes an 1100-ton machine was used.

The pressure was applied as slowly and as gradually as such machines will permit, which leaves much to be desired. The first indication of noticeable deformation was given by the flaking off of the sides, exposing the embedded nails. This may be termed the elastic limit, but it was not recorded in all cases. Where recorded, the elastic limit varied from 60 to 80 per cent. of the ultimate strength.

The crushing strength was considered to be attained when the deformation became excessive. After this point was reached the cube was rapidly squeezed without any increase in pressure; on the contrary, the pressure could be much decreased. When the squeezing was carried sufficiently far the cube would break apart when removed from the machine and dropped on the floor.

The results of the tests as tabulated speak for themselves; little can be added in discussing them. The most striking fact is that the greatest resistance of 17,800 lbs. per sq. in. was obtained on a cube 15 months old, a figure unheard of in the annals of reinforced concrete testing. That this figure is not accidental is borne out by the fact that the companion test cube developed a resistance of 16,670 lbs. per sq. in., and that two 12-inch cubes, reinforced by 25 per cent. more nails than the other cubes, attained in 8 months a resistance of 15,300 lbs. per sq. in. without failure, the limit of the largest machine having been reached.

The most important phenomena developed are, however, the comparatively high resistances obtained within 7 days and 1 month, and the small variations in the strength of the various cubes at the age of 7 days. The average compressive strength developed by 17 cubes, as will be seen from the table, was 3,010 lbs. per sq. in., with a minimum value of 2,770 and a maximum of 3,330 lbs. per sq. in., or about 10 per cent. either way. The average strength of 15 cubes at the age of 1 month reached 5,818 lbs. per sq. in., an increase of 93 per cent. in 3 weeks. The growth in strength of the cubes with their age can be plainly seen from the table.

The cube reinforced by cut wire, instead of wire nails, failed

at the age of 7 days at 1,945 lbs. per sq. in., or under a pressure of only two-thirds of that of the wire-nail cubes. The two scrap iron cubes, while somewhat stronger, did not make a better showing.

From the proportion of wire nails used, the high cost of such concrete is at once apparent. Eighty-eight pounds per cubic foot of concrete, or 18 per cent. by volume, is certainly expensive reinforcing. The cost of concrete so reinforced will be about \$2.30 per cubic foot, so high as to preclude its use to any considerable extent. There are, however, many instances where a material which combines so high a compressive resistance with the advantages of concrete, will find its applications. Thus, for instance, where column footings are to be raised or the foundation has settled, it might be found very convenient to utilize concrete reinforced by wire nails to fill the spaces. The plasticity of the material which can be made to fill all kinds of spaces, and the great strength developed in 7 days, will be of sufficient advantage in many cases to cause its adoption.

Aside from the practical considerations of utilization, the tests described in this paper have a theoretical bearing. They illustrate in an extreme manner how the compressive strength of a material may be increased by reinforcing its shearing resistance. The nails actually reinforce the shearing planes in all possible directions and thereby develop the high compressive resistance of the material. The tests thus shed a light on the internal stresses of a body in compression.

The tests were made in the Cement Testing Bureau of the Department of Bridges of the City of New York, and the information given in the above is offered for the free use of the engineering profession *pro bono publico*.

DISCUSSION.

MR. I. H. WOOLSON. —I am rather interested in this subject, **Mr. Woolson.** because some two years ago I had occasion, in connection with some investigative work for the Clark Foundation Company of the City of New York, to make some tests of concrete cubes reinforced with jack-stones.

The investigation was along this same line of getting a bond. In a 6-in. cube, reinforced with jack-stones (the little cast iron toys that children use), we got between 7,000 and 8,000 lbs. per sq. in. in 30 days. The plan did not work very successfully because of the breaking of the jack-stones. They went off like fire-crackers, and kept it up throughout the test. Of course it was simply an experiment.

It was quite evident that had those jack-stones been made of ductile material, the concrete would have been excessively strong. Later, within the last two months, we made some other tests the same way, by using small steel punchings in the concrete, but apparently these were no better than ordinary medium-sized gravel. If we could get somewhere punchings from sheet metal that are not uniform in size and which could be bought cheaply, it is possible that such a concrete could be used in many places to advantage. The punchings ought to be cheaper than wire nails. It is not a case of bond so much as it is of the locking of the metal pieces. We carried on these investigations when making a foundation for an engine, which required something that would be certain to stay in place.

MR. EDGAR MARBURG. —It is doubtless well known that for **Mr. Marburg.** many years steel turnings have been used in concrete intended for engine foundations or other severe service conditions.

MR. WOOLSON. —It has been suggested that there is any **Mr. Woolson** quantity of old wire fencing that the farmers do not know what to do with, which might be cut up into short lengths and used in concrete.

PAINTS FOR CONCRETE: THEIR NEED AND REQUIREMENTS.

BY G. D. WHITE.

It was not my original intention to present at this meeting a paper on paints for concrete. My purpose was rather to open a discussion, with a view of eliciting not only a general discussion but, if possible, some action by Committee E of this Society to determine the most desirable and best suited coating for the treatment of concrete and concrete structures.

The use of concrete for building purposes has been of comparatively recent origin. From its real beginning about forty years ago, the demand has increased, gradually at first, but with phenomenal growth during recent years. This remarkable development is shown by the large amount of cement used during 1907 and 1908 as compared with twenty or even ten years ago. This marvelous growth can be explained in two words: economy and adaptability.

Concrete for building purposes in any form, however, like all building materials that are practical and plentiful, is not consummate. Unless extreme care is exercised in the preparation, mixing, and workmanship for plain or reinforced work, the resulting concrete is not uniformly impervious to moisture. Where perfect materials have been used with perfect workmanship, we have another problem to solve. Concrete is a non-conductor of heat. The difference in temperature between the concrete wall and the atmosphere—the warmer the day the greater this difference—causes a condensation of moisture on the surface. This is annoying and detrimental to health in living and office rooms; a loss of room or loss by damage in store-rooms and warehouses; and an objection to any building whatever its nature or purpose.

Hollow concrete blocks, tile, brick, etc., have serious defects. They are not only porous but capillary positive, and thus absorb moisture from 5 to 40 per cent. of their own weight. Due to rain and snow walls built of these materials become water-soaked,

and remain in that condition for varying lengths of time. During certain seasons of the year and especially in some sections of our country, they remain soaked for months. The fact that dry walls are essential to health and comfort is generally known and so well appreciated that the question of dampness has retarded a much larger and more extensive use of concrete by the building trades of this and other countries. The tendency to stain, the frequency of efflorescence, and the difference in color due to difference in materials and to intermissions in concrete, are defects of a less serious nature.

A drawback that includes concrete in all forms is the uninviting, unattractive color. Replace our buildings of marble, terra cotta, granite, or wood, handsomely decorated, with buildings of concrete and note the contrast. The dirty gray of ordinary cement or concrete becomes monotonous to the observer, even where there are but a few concrete structures among other buildings of more pleasing construction.

If to the strength, cheapness, durability, and fire-resisting properties of concrete can be added decoration and impermeability to moisture, we will have a building material as nearly perfect as the world has ever seen, and this within the means of every builder. In recognition of this fact, various concerns and individuals have placed upon the market and recommend as a solution to the problem, various treatments and coatings, which, for the sake of convenience, I will divide into four classes. In my investigation of the different treatments and materials included in these classes, I have endeavored to be unprejudiced and to give each its true worth and full value.

I. WATERPROOFING COMPOUNDS IN LIQUID OR POWDER FORM, MIXED WITH THE CONCRETE IN ITS PREPARATION.

This is a help in that it lessens and retards, in a measure, the moisture absorbing tendency of concrete. It fails in the desired attainment for the following reasons:

- (a) Improper distribution, which is difficult of regulation.
- (b) When properly distributed, it does not render concrete entirely impervious to moisture.

(c) It has a tendency to weaken the tensile strength of concrete.

(d) It does not decorate.

(e) The increase in value is not proportional to the increase in cost.

(f) It deteriorates with age; i. e., a concrete block containing the waterproofing compound will absorb certain varying quantities of water on the first application. On subsequent applications, allowing the block to dry in each instance, larger quantities are absorbed.

2. TREATMENTS PREPARATORY TO THE USE OF LINSEED OIL PAINTS.

Personally, I would be prejudiced in favor of this process if it offered even a partial solution to the problem.

Treatments in various forms have been advanced and recommended by some of our leading master painters and endorsed by most able research chemists. For the sake of brevity I have included in my paper but three of these treatments:

(a) Muriatic acid wash.

(b) A wash consisting of a solution of zinc sulphate and water.

(c) A wash consisting of ammonium carbonate and water.

From a chemical standpoint muriatic acid, regardless of its strength or the character of the concrete, is not only useless as a remedy, but detrimental in its action. Master painters who have endeavored to use it in practice have discovered to their sorrow a confirmation of the chemical theory.

Theory favors, and practical tests confirm, the second method rather than the third as the best adapted to the purpose. In the former we have produced calcium sulphate and zinc hydroxide through the action on calcium hydroxide contained in or liberated by the setting of the cement; in the latter we have the formation of calcium carbonate, water, and ammonia.

In the manufacture of chemicals and chemical colors, we can standardize our solutions by the use of molecular formulas and thus produce the product desired without the waste of any single

ingredient, excepting perhaps water. Unfortunately, in preparing concrete surfaces to receive paint, we have no way in which to determine the strength of solution to be employed. Were such a determination possible, we would have to make it for every different piece of concrete, and in the case of blocks, for every block, because we could not be sure of uniformity. Knowing even the required strength of solution, we still lack a method of application that will insure proper neutralization and uniform results.

Zinc sulphate and ammonium carbonate as applied to concrete, unless fully satisfied by the presence of calcium hydroxide, are still soluble in water and thus offer difficulties of a serious nature. The neutralization of calcium hydrate and calcium oxide appearing on the surface of concrete does not always mean that the surface will remain neutral. Moisture finding its way from the inner portions of the block or wall carries with it alkali—the foe of linseed oil paints.

The treatment with zinc sulphate or ammonium carbonate, even though successful, does not offer a solution to the problem, because a linseed oil paint is unsuited for either exterior or interior painting of concrete. The gloss robs the surface of the appearance of stone or masonry. Linseed oil has water absorbing and lacks water resisting properties. It cannot be applied over a damp or wet surface, which means that following a rain storm or rainy season a painter must wait weeks and perhaps months before he can commence work or complete a contract already begun. A series of practical tests developed the fact that a wash of zinc sulphate or ammonium carbonate was a help in some instances, but the lack of uniformity in results and the low degree as well as the non-permanency of improvement, demonstrated their inefficiency to cope with this important problem.

Before leaving this phase of my subject, I wish to say that the above is not intended as an adverse criticism of the master painter or chemist recommending the use of these treatments. On the contrary, they are to be commended for their wisdom and research in devising a method or process that helped to overcome, in a measure, at least, the difficulties confronting them.

3. COLORLESS LIQUID COATINGS.

Certain of these may be of some value in retarding moisture absorption and efflorescence, but all are found lacking in the following respects:

(a) They serve to emphasize any defects, or difference in color, of concrete construction.

(b) They impart to concrete a soggy, water-soaked appearance.

(c) They do not render the concrete impervious to moisture for any length of time.

(d) They do not decorate.

4. PAINTS FOR CONCRETE.

If there is any truth or logic in the foregoing, it would appear that we need, and the building trades demand, a paint peculiarly adapted to the coating of concrete surfaces. The requirements are exacting, and from my study of this problem I conclude that a paint to meet the demands must embody the following properties:

It must be a durable protection, and a preventative of dampness through resistance to moisture.

It must be a paint that can be applied directly to the concrete surface without any previous treatment, and which, after weathering, will offer a good surface for repainting.

It must be capable of receiving and holding a plaster coat.

It must be economical, and so constituted that it will be artistic, appropriately pleasing to the eye.

Its consistency and nature must be such that it will spread easily, work well under the brush, penetrate the voids, fill and cover hair cracks, and act as a bond of connection between the concrete and succeeding coats. Not only must it penetrate and fill up the voids, but it should, in a measure, level up the rough portions of the surface.

It must be suited to painting over damp and wet surfaces, and dry even when surrounded with moisture. When dry it must adhere to the surface, be sufficiently hard to resist frictional influences, sufficiently elastic to conform to changes in temperature, and remain hard in the presence of moisture.

It must be composed of both pigment and vehicle, neither of

which should be detrimentally affected, physically or chemically, by the liberated calcium hydroxide.

As in paints for wood or iron, the vehicle in a paint for concrete is a very important factor. It must not be linseed oil, glue, casine, or any substance with similar characteristics. It should be difficult of saponification, and of low saponification number. I am convinced that some kind of varnish product, especially adapted to the purpose, is required. The pigment, as in linseed oil paint, has its function to perform. In opposition to the theory advanced by some, I am of the opinion that this pigment should not be cement for reasons that are self-evident. It must be, for the first coat, at least, alkali proof. Not only must it decorate, but it must protect the vehicle and, in conjunction with the vehicle, the surface coated.

A paint consisting of both pigment and vehicle working in unison, favorable of application, serviceable under exposure, resistant to moisture, and economical, is necessary to meet satisfactorily the requirements of a paint for concrete.

DISCUSSION.

Mr. Rinald. MR. C. D. RINALD.—My knowledge of this subject is purely academic and not based on any experience or experiments of my own. It is claimed that the addition of a very small quantity of calcium chloride to the water with which the concrete is mixed will favorably affect the setting of the cement by retarding the initial and accelerating the final set. This is supposed to give the whole mass of cement or concrete a chance to crush out the voids by its own weight and thus to become more compact and waterproof. The theory looked so plausible that a friend of mine decided to give this method a trial. He told me some time ago that the result was quite satisfactory. He dissolved 3 lbs. of calcium chloride in 25 gallons of water, which is equivalent to 1.5 per cent. by weight, and he used this solution exclusively in mixing the cement for the cellar walls in an office building. The originators of the process state that if either much more or much less than 1.5 per cent. of calcium chloride be used the results will be unsatisfactory, because then the initial and final set will no longer take place at practically the same time.

Mr. Dewar. MR. JOHN DEWAR.—I have listened with interest to the reading of Mr. White's able paper, having been intensely interested for a number of years in the painting and coating of cement structures, and especially in the prevailing style of architecture, the Elizabethan or old-English half-timber houses that are being erected all over this country and Canada. We have found a great deal to contend with in the action of the alkalies and other chemical properties of the cement on our oil-paint coatings, and also in the action of the oil itself on the cement structure; all of which leads me to the same conclusion that the writer of the paper has reached, that linseed oil in the paint coating is an improper vehicle to apply to the surface of cement.

Let us consider the modern house architecturally, as I am more interested in that than in large concrete structures. First, on the exterior metal lathing there is placed a rough coating, then a final coating of sand and cement worked to a hard even surface, which may be $\frac{1}{8}$ to $\frac{1}{2}$ in. or more in thickness, depending altogether

upon the result of the first coating of the cement groundwork. **Mr. Dewar.** The linseed oil weakens the bond between this skin coat and the foundation coat. There is no question about that, the result being that the skin coat of cement falls off in flakes in a short time. This indicates the necessity of using some substantial petrifying liquid in place of the oil.

I received a letter from one of the most prominent master painters of this country, calling attention to the necessary preparation of the cement for the paint coatings, from which I should like to quote the following extract in somewhat condensed form:

You will remember my appreciation of the paper read at the Baltimore Convention by Mr. Charles MacNichol of Washington, D. C., on the painting of cement and concrete, as I had a contract at that time on which I could try it. As you expressed a desire to know the result, I feel you will be interested in a test even more severe than the one I had in mind at that time. I must go into the matter somewhat in detail, as conditions have so much to do with results.

I was called in by the Riter-Conley Manufacturing Company, who had built a reinforced concrete office building at their Allegheny Works, with walls, ceilings, floors, and partitions of steel and Portland cement concrete. The plaster for walls and ceilings was composed of 1 : 2 Portland cement mortar, rough finished. They had been told by experienced engineers that the walls and ceilings should be allowed to stand for a year unpainted, but had decided to refer the matter to me. I told them the painting could be done without waiting, and they authorized me to go ahead in my own way.

With no heat in the building and condensation running down the walls and dropping from the ceilings, the conditions looked very bad. Open gas fires were put in each room and allowed to burn about 3 weeks, at which time the plaster was in such a condition that the painting could be started. I bought 300 lbs. of zinc sulphate at $3\frac{1}{2}$ cents a pound, and mixed it with an equal amount of water by weight, according to the formula in Mr. MacNichol's paper, and applied it as a sizing which also helped to stop suction. I then painted it in the usual way with oil paint, the finishing coats being light green. There is not a sign of discoloration where this method was followed. In one room where the men used a weaker solution on account of running short of zinc sulphate, the plaster showed some discoloration, proving that the proportions mentioned should be adhered to.

Now the light green to which he refers is one of the most severe tests, since it is very susceptible to the action of alkali.

THE PRESIDENT.—How long ago was this work completed?

The President.

MR. DEWAR.—About 4 months.

Mr. Dewar.

Mr. Thompson.

MR. G. W. THOMPSON.—I want to say a word on painting concrete. I have no knowledge of what was stated in the paper except that I am told that the writer condemns the use of linseed oil in paints for concrete. Now that is an extreme position. You might as well say that you cannot paint simple neutral carbonate of lime with a linseed oil paint. Concrete when freshly made is caustic, and yet if it is aged long enough any good paint containing linseed oil will stand well on concrete, or cement, or any structure involving the use of cement. That is due entirely to the setting of the concrete and the absorption of carbonic acid, which changes the caustic constituents into neutral substances which are fairly inert with reference to linseed oil. I say "fairly inert;" I am not going to say that paint on concrete will last forever any more than it will anywhere else.

There have been references here to the use of various reagents for treating concrete and similar surfaces to put them in condition for painting. I may be covering some of the ground which has already been gone over, but I will say that last year I read a paper here on certain tests for paints, in which, generally speaking, I condemned the use of anything in paint intended for outside exposure that was soluble in water. Now on the same ground I would condemn anything in materials for treating concrete that forms a compound soluble in water. Therefore I would condemn sulphuric acid and muriatic acid, unless they are thoroughly washed out, which seems to be almost impracticable. There seems to be less objection in the case of sulphate of zinc. I do not wish to condemn sulphate of zinc, because sulphate of zinc is an excellent material for inside work where it is not exposed to rain water. When applied to concrete, sulphate of zinc will form sulphate of calcium, which is more or less soluble. I believe that even after treatment of concrete with sulphate of zinc it ought to be washed.

I suggested a year ago that carbonic acid water was the best material which could be used, simply carrying out the natural ageing by accelerating the ageing of the concrete or similar material; in other words, take the ordinary siphon of a carbonic acid water, or take a cylinder and connect it up with a spray, any way you choose, apply it to the concrete surface, and you will obtain a very rapid ageing of the surface. It has been suggested that carbonate of ammonia should be used. Carbonate of ammonia

does the same thing that carbonic acid does, but it has this one disadvantage, that ammonia is apt to be temporarily fixed by the alumina and other constituents of cement and it will be gradually given off. Those who have had experience with ammonia on paint know that it will discolor white paints. Take a glue size even and put it on the surface of fresh plaster, and the action of the lime on the glue will liberate the ammonia so that when you come to paint over it with a white paint the paint will turn yellow in a very short time simply because of the action of the ammonia on the oil. The only safe procedure it seems to me is to use carbonic acid. Mr. Thompson.

I do not want to condemn sulphate of zinc, because it seems to me that next to carbonic acid it is the best thing. If it is found by practice that I am wrong I am willing to change my views, but I still have to take the stand that the use of any material which will produce a water-soluble constituent is to be condemned.

Painting concrete is not a difficult matter where the concrete is reasonably old. The trouble is to paint it when it is fresh. I have seen concrete so fresh that when painted with blue paint it would turn yellow from the bleaching of the Prussian blue; but after it had aged and the lime had changed to carbonate of lime there was no trouble.

MR. DEWAR.—Mr. MacNichol, a master painter of large experience, recommends sulphate of zinc as an under-coating for paints on concrete and cement structures. He has used it on actual work for over twenty years. Mr. Dewar.

MR. G. E. THACKRAY.—I must confess to a certain lack of knowledge on the subject in question, but it strikes me that the coloring of concrete walls or structures by the old-fashioned way of mixing an inert pigment with the base material, forms a more substantial coating in many respects than any paint that may be externally applied. Of course I understand also that in doing this, one can only obtain neutral shades of color and that bright effects cannot be had, but I fancy that in most constructions of this kind the latter are not desired. By so doing, permanent coloration is obtained and if the surface should become dirty by lapse of time, it could be washed or sand-blasted to refresh it. It therefore strikes me that the painting of the surface of concrete structures is a half-way measure and that the proper way would be to color the mass. Mr. Thackray.

DISINTEGRATION OF FRESH CEMENT FLOOR SURFACES BY THE ACTION OF SMOKE GASES AT LOW TEMPERATURES.

BY ALFRED H. WHITE.

The demand for speed in the construction of buildings is leading to a progressively greater use of concrete in cold weather. The setting of hydraulic cement is a chemical process which, like all others, proceeds more slowly in cold than in warm weather; but so far as the chemical process is concerned, if sufficient time is allowed for this slower hardening process and actual disruption of the concrete through freezing does not take place, concrete thus used should ultimately be as good as that hardening under more favorable temperature conditions. From practical observations it has, however, sometimes been thought that an unfavorable effect attendant upon an excessively retarded set was caused by the settling of the finer and specifically heavier cement, so that the top coat when finally hardened was poor in cement and hence friable.

To this cause of trouble is now to be added another which, so far as the author is aware, has never before been observed in practice, and which was called to his attention by the behavior of the newly laid surfaces in a large eight-story reinforced concrete warehouse. The floor surfaces were laid during the months of December and January, the window openings being closed and fire pots kept going so that the temperature never actually dropped to the freezing point. At the time of the writer's visit in February the floors appeared to be in good condition, but a few scrapes of the shoe produced evident abrasion and it was easy to rub a hole about $\frac{1}{8}$ in. deep.

The following data were furnished relative to the manner of laying the floors. The concrete floors had been covered with about a 1-in. coat of a mixture of one part of cement to two parts of crushed granite. At first it had been mixed decidedly wet and applied to wetted floors. As poor results became apparent, variations both in mixture and method of application had been tried.

The cement had passed the architect's tests, and the architect's samples on re-examination satisfied the required standard. The crushed granite possessed a fair gradation in size of particles, as shown by the following mechanical analysis:

100.00

This failure to find the trouble in the raw materials directed attention more particularly to the conditions surrounding the hardening process, and especially to the effect of the carbon dioxide of the gases from the open braziers on the slowly setting cement. Analytical methods could avail but little here, so direct experiment was resorted to. It was desired to investigate the effect of setting at temperatures very little above the freezing point, both in ordinary air and in an atmosphere rich in carbon dioxide; and to further study the effect of an impervious base corresponding to a thoroughly wetted concrete foundation, as compared with the effect of a dry porous base which would absorb the excess of water from the concrete and thus rapidly and mechanically cause enough rigidity to prevent the differential settling of the very fine particles of cement.

The experimental method was as follows: To obtain a uniform and porous base, small dishes of unglazed clay—the scorifiers used by assayists,—were employed. These were thoroughly soaked in water before use, but the evaporation of the water from the outside of the dish still caused a relatively rapid absorption of water from the concrete within the dish. To obtain the

non-porous base, other similar dishes were soaked in melted paraffine and then allowed to drain and cool. Two separate series of tests were made with different cements and the crushed granite mentioned before from which everything not passing a 20-mesh sieve had been sifted out. One part of cement was used to two of granite and enough water added in the mixing to make the mixture jelly-like in the molds, which were at once placed in the cold room where they were to be observed.

Since there is no quantitative way of measuring the friability of a surface, it is hardly worth while to repeat the details of the tests. They all agreed in showing that the pats which had set in ordinary pure air at a temperature of from 36° to 38° F., and had taken from 7 to 8 hours for their initial set, gave slightly dusty surfaces; but that the pats which had hardened under exactly the same conditions with the exception that the air above them had contained about 6 per cent. of carbon dioxide, had surfaces which could be rubbed to dust very readily with the fingers. The harmful effect of the carbon dioxide was unmistakable.

The tests on the effect of absorbent or non-absorbent bases did not yield nearly such conclusive results, and it was not always possible to detect much difference between them. A chemical analysis of sweepings from the floor of the warehouse mentioned above showed in one case only 40 and in another 46 per cent. of material insoluble in dilute acid and alkali, which may fairly be held to indicate the proportion of granite in this disintegrated surface. Inasmuch as the material as laid was supposed to be 66 per cent. granite, it indicates, even after making allowance for the absorption of the carbon dioxide, that there had been a decided concentration of cement on the surface instead of an impoverishment which would have weakened it. These tests do not indicate that the effect of the slow setting, as apart from that of the carbon dioxide, had been of great importance.

After this conclusion had been reached experimentally, a reference to this subject was found in Le Chatelier's classic "Constitution of Hydraulic Mortars," published twenty years ago, an extract from which follows:

However, a hydrate $\text{CaCO}_3 \cdot 5 \text{H}_2\text{O}$ exists which can be produced by the carbonation of lime below 41° F., but it is very unstable and the least rise in temperature transforms it into pulverulent anhydrous calcium

carbonate devoid, consequently, of all strength. It may be useful to take account of this fact in the hardening of cements at low temperatures, especially for experimental briquettes exposed to the air or placed under a thin layer of water.

It is only within the last few years that modern building methods have given rise to conditions which would cause trouble from this source, and it has, so far as the author is aware, never been brought to the attention of engineers. He has felt justified, therefore, in presenting the first case of injury from this cause which has come to his knowledge, together with an experimental verification of the cause of the trouble. It will be of interest to add that, although various remedial paints were tried on these floors, the only effective treatment was to grind them down with stone rubbers and carborundum to a hard surface.

Conclusion.—Smoke gases, on account of their carbon dioxide, exert a very harmful effect on hydraulic cement setting at a temperature below 42° F., an unstable hydrated calcium carbonate being formed which at only slightly higher temperatures effloresces with complete loss of its bonding properties. This action is a superficial one and would probably not weaken structural concrete appreciably, but merely cause dusting of the surface. The effect is most noticeable on floors. It is probably never advisable to lay the top coat of floors in rooms which are being heated by open fires, but if this is unavoidable the temperature should be kept safely above 45° F. A higher temperature will act advantageously in preventing an excessively slow initial set of the cement.

SOME RESULTS OF DEAD LOAD BENDING TESTS OF TIMBER BY MEANS OF A RECORDING DEFLECTOMETER.

BY HARRY D. TIEMANN.

These dead load tests which the United States Forest Service has been conducting for the last three years are made upon a machine which was designed by the writer for the purpose, in which the deflections of a series of five beams under dead load are recorded automatically and simultaneously upon a drum which makes one revolution in 30 days. The history of each of the five beams is thus permanently recorded for any desired length of time by the tracings of the markers upon a sheet of cross section paper wound upon the drum. The apparatus is so designed that each horizontal inch of the cross section paper represents 24 hours of time, and each vertical inch a deflection of 0.2 in. It is intended to be accurate to within 0.005 in. The size of the specimens for these tests is 2 by 2 ins. in section with a span of 36 ins., the load being applied in the center.

As this apparatus was described and illustrated by Mr. McGarvey Cline last year in his paper published in the Proceedings, Vol. VIII, pp. 535-590, it will be unnecessary to give a further account of it here.

While it is too early as yet to draw final conclusions from the results of these tests, it is possible to obtain at least indications of and approximations to some of the fundamental laws, and to obtain some idea of the limits of safe loading.

Before critically examining the results, it should be distinctly noted that it is practically impossible to obtain two beams exactly alike, having the same strength and stiffness and behaving in all respects the same. Therefore, although the specimens were selected with great care, considerable variation inherent in the material itself is to be looked for, and the relations of cause and effect are frequently obscured on this account. Whenever a

single comparative result between two tests follows a certain action, it leaves an open question whether it was due to the action or to differences in the specimens. If, in comparing it with another similar case, the same comparative result is shown, the inference is that it was due to the given action, but if the reverse be true the contrary must be concluded. Further coincidences establish the conclusion with greater certainty and the correct interpretation of the results in establishing a law must be largely a matter of degree, dependent upon the number of coincidences and the nature of the problem. The deductions are better obtained thus by a *comparison* of results, rather than by actual numerical values. By the nature of these tests, the method of making a great number and averaging the results to obtain the result sought after is impracticable, at least for some time to come, since to obtain enough tests for reliable averages would require a great many years or a large number of machines the expense of which is prohibitive. The former method just described by comparison of coincidences, though much more difficult of analysis, has been the one aimed at in these experiments.

The method of operation has generally been to place a series of five beams cut from the same plank and as nearly alike as possible upon the machine at the same time, and to load each one differently. In some cases an initial dead load was placed upon the beam and left until rupture; more often, however, the loads have been varied from time to time according to the nature of the problem. A sixth specimen is generally included in the series and tested in the usual manner upon a power machine, and also an extra one placed with the other beams and weighed from time to time as a moisture indicator. The moisture content of this extra piece is afterwards determined and thus made known for each weighing, which is reasonably assumed to apply to the other beams similarly situated.

The tests thus far have all been made with dry longleaf pine. Four series have been nearly completed. (Two beams of the last series are still under test, having not yet failed.)

The records of the drum have been copied, combined so as to begin at the same point, and the horizontal time scale foreshortened to one-fifth for convenience. The curves thus obtained are shown in Figs. 1 and 2, and Figs. 3 and 4, Plate IX.

Briefly summed up, the deductions, which must be regarded as provisional, are as follows:

1. The deflections or recoveries produced by the immediate addition or removal of loads are independent of any deflection or recovery due to the time effect of dead loads, up to the elastic limit, and probably to the point of first failure; that is to say, they are the same as would have been produced had there been no dead load upon the beam. In other words, if the deflections or recoveries due to the time effects of dead loads be subtracted from the stress-deformation diagram, the resulting diagram is the same as would have been obtained in the usual machine test. This statement may subsequently be modified somewhat by an answer to the question as to whether the elastic limit is raised by the time effect of a dead load. The conclusion is clearly shown by the stress-deformation diagrams, Figs. 5 and 6.

2. If a beam be subjected to a dead load which is less than its "immediate"* elastic limit at the time of removal of the load, and the load be removed before any failure occurs and the beam allowed to recover for a length of time, neither the ultimate strength nor the elastic limit as shown by the usual power machine test are reduced thereby. It appears that the latter may even be raised somewhat. The stiffness (immediate modulus of elasticity) also is not changed by the dead load. These results are shown by Series I, Fig. 1, and that the stiffness does not change is likewise shown by the load-deflection diagrams of Series III and IV, Figs. 5 and 6.

3. The greener the wood the more plastic it is under dead load, and apparently a smaller proportionate loading will cause a continual deflection until rupture finally occurs. Beams under dead load deflect more during variations in atmospheric humidity than at the average constant humidity, for during damp weather the deflections increase while in dry weather they become less or may cease altogether, but in so doing the previous deflections during the damp period are not regained. Thus the beam may continue to deflect by a series of successive stages until failure occurs, due to changes in the humidity of the air. That is to say,

*By *immediate* elastic limit is meant that shown by an immediate or "live" load, as by an ordinary machine test, in contradistinction to that indicated by a dead load or time test.

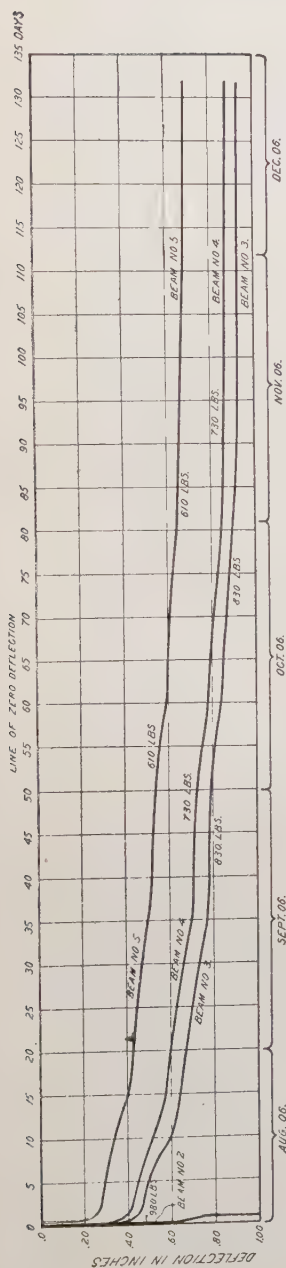


FIG. 1.—Autographic records of the four beams of Series I.

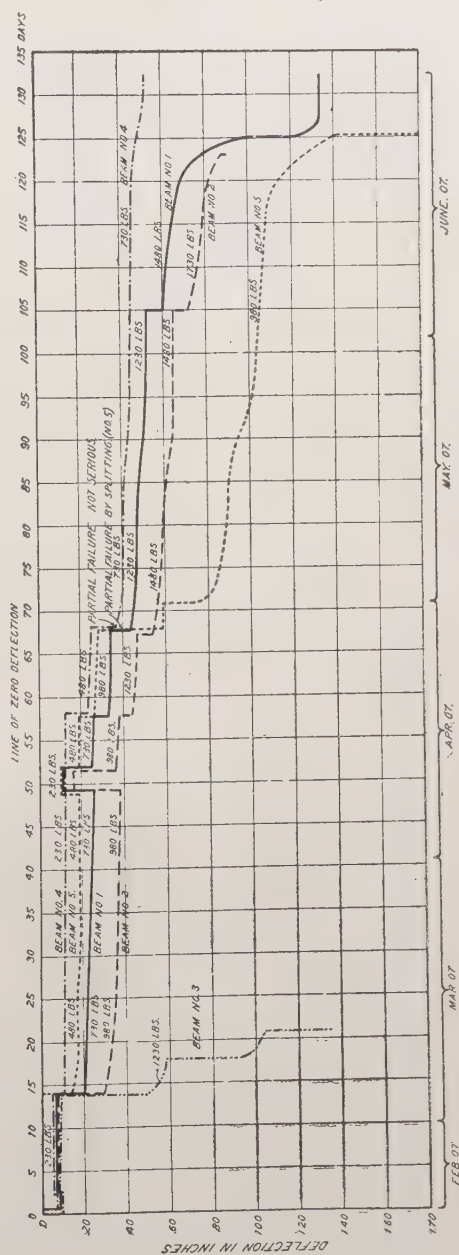


FIG. 2.—Autographic records of the five beams of Series II.

injurious effects produced by dampness are cumulative and are not compensated for by subsequent dryness.

4. Dry longleaf pine beams may be safely loaded permanently to within at least 75 per cent. of their immediate elastic limit, provided no increase in dampness occurs, and deflections will ultimately practically cease under this load. No perceptible deflection will occur due to the time effect under loads up to within 20 per cent. of the immediate elastic limit. Loads greater than the immediate elastic limit are dangerous and will generally result in rupture if continued long enough. The proportions given above are for uniform moisture conditions. If the beam becomes drier during the period of loading, the actual elastic limit is of course raised, which is beneficial; but if it becomes damper the reverse is true, and what was at first a safe load may thereby become dangerous. It must be understood that these statements are only tentative, being based on the results so far obtained, and must be substantiated by comparison of further coincidences. A beam which has completely ceased to deflect under a certain dead load may again begin to deflect and even rupture under the same load, due entirely to an increase in its moisture condition from damp weather. This fact is strikingly shown in Series III, Fig. 3.

5. The recovery of the time effect of a beam after removal of a dead load is gradual, and very similar in reverse order to the deflection under dead load. This, it will be understood, does not refer to the *immediate* recovery, which has been shown under (1) to be always the same whatever the deflection due to time effect. The recovery of the time effect due to the removal of dead load continues longest in the beam which has been most heavily loaded, and is not always complete, the permanent "set" apparently being larger the greater the time effect under dead load.

6. With beams under dead loads in general, if the continual deflections diminish during equal successive periods of time, the indication is that the load is safe and that deflection will ultimately cease under the same or drier moisture conditions; but if the continual deflections appear to increase, the load is unsafe and rupture is almost certain to follow.

Without taking up each individual test in detail, I will discuss them only in so far as they bear upon the results specified,

Series I was started August 1, 1906, and consisted of six beams, only four of which were subjected to dead load. These were each loaded permanently with a different proportionate load. The heaviest loaded failed in 1 day, and the load was removed from the remaining three in December after being on for 132 days. The beams contained 22 to 23.5 per cent. moisture when first loaded and only 10 per cent. when the loads were removed. After resting for over a year, the remaining three beams were finally tested in the usual manner on a power machine. The other two beams, Nos. 1 and 6, were likewise tested by way of comparison, but without dead load, No. 1 being tested at the start, and No. 6 together with the other three. After reducing the values to the same moisture content and same dry specific gravity, the proportionate dead loads were as shown in Table I.

TABLE I.—RATIOS OF DEAD LOADS TO ESTIMATED STRENGTH.

Beam No.	Dry, specific gravity	Ratios of actual to estimated stress deduced from the sample beam.				Set after removal of load, inches.	
		At original moist- ure conditions.		At final moisture conditions.		At first.	Perma- nent.
		To F*	To R*	To F*	To R*		
1. Sample ma- chine test...	0.56	1.	1.	1.	1.	.....	.....
2.	0.53	1.78	0.87	failed in 25 hrs.		.....	.....
3.	0.55	1.41	0.69	0.92	0.45	0.67	0.48
4.	0.57	1.20	0.59	0.78	0.38	0.60	0.35
5.	0.58	0.87	0.42	0.55	2.27	0.47	0.40

The power machine tests on the six beams, when reduced to correspond to a uniform moisture content of 10 per cent. and a dry specific gravity of 0.56, gave the values in Table II.

These values must be taken in general terms only, owing to the non-uniformity in single specimens. They indicate fairly well, however, that little or no loss of strength is shown in beams Nos. 3, 4, and 5, which had sustained the dead load. The apparent loss in the modulus of elasticity is not significant, since the moisture reduction curves show considerable variability for single specimens. Conclusion 2 is based upon this series.

* In Tables I and II,

F = stress at elastic limit.

R = modulus of rupture.

TABLE II.—COMPARISON OF STRENGTH VALUES OF THE THREE BEAMS NOS. 3, 4, AND 5, AFTER A DEAD LOAD FOR 136 DAYS, FOLLOWED BY A REST OF OVER ONE YEAR, WITH THOSE OF THE TWO BEAMS NOS. 1 AND 6, NOT SUBJECTED TO A DEAD LOAD, AFTER REDUCING ALL VALUES TO A MOISTURE CONTENT OF 10 PER CENT. AND SPECIFIC GRAVITY OF 0.56.

Beam No.	Treatment.	Power-machine Tests. Reduced Values, lbs. per sq. in.		
		F	R	E
1	Tested without dead load	6,290	12,880	2,210,000
3	Dead load of 0.92 F for 136 days. .	7,480	12,410	1,860,000
4	“ “ “ 0.78 F “ “ “ . .	8,580	9,900	1,680,000
5	“ “ “ 0.55 F “ “ “ . .	7,890	13,950	1,800,000
6	Tested without dead load	6,560	*	2,095,000

Series II consisted of six longleaf pine beams thoroughly air-dry at start, beam No. 6 being tested at once on the power machine. The tests were started in February, 1907, with a moisture content of 10 per cent., which increased to about 15 per cent. during the summer after the furnace fires were out. They were run for a while with a 230-lb. load until March 4, when each beam received a different load as follows:

Beam No. 1—	730 lbs.,	approximately	60 per cent.	of elastic limit.
“ “ 2—	980 “	“	80 “	“ “ “
“ “ 3—	1,230 “	“	100 + “	“ “ “
“ “ 4—	230 “	“	20 “	“ “ “
“ “ 5—	480 “	“	40 “	“ “ “

The values from beam No. 6 can not be applied to the other individual beams, except in a very general way. The estimation of the load at the elastic limit of the five beams as 1,200 lbs. is only a very rough approximation, arrived at by a comparison of the load deflection diagrams of all the beams.

With these loads, the following results occurred. Beam No. 4, loaded to only 20 per cent. of its elastic limit, deflected practically not at all under this dead load. Beam No. 5 with about 40 per cent. load ceased to deflect in about 20 days. Beam No. 1, loaded

* Beam No. 6 failed prematurely due to an imperfection.

with about 60 per cent. of its elastic limit, was deflecting slightly after 44 days. Beam No. 2, loaded to about 80 per cent., was still deflecting after 44 days. Beam No. 3, apparently loaded just beyond its elastic limit, deflected rapidly and began to fail in 4 days. After 35 days the loads were removed from all the beams to 230 lbs. and reloaded again in 3 days. The immediate recovery and deflection is seen to be independent of the time effect. After 44 days another load of 250 lbs. was added to each beam, and again in 10 days. At this point the beams contained approximately 10 per cent. moisture, about the same as when started. Beams Nos. 4 and 5 partially failed by splitting, but No. 4 was apparently not injured significantly thereby; No. 5, however, had practically failed. In 37 more days, on June 3, the three remaining beams, No. 4 with 730, No. 1 with 1,230 and No. 2 with 1,480 lbs., had almost ceased to deflect, and another 250 lbs. was added to Nos. 1 and 2. The conditions were then as follows:

Beam No.	4—	730 lbs.,	nearly constant.
"	"	1—1,480 "	deflected rapidly.
"	"	2—1,730 "	deflected very rapidly.

Probably the elastic limit had increased by this time, due to drying slightly.

By the middle of June, when the furnace fires had gone out and warm damp weather set in, a marked increase in the rates of deflection of all three beams occurred, and Nos. 1 and 2 failed in a few days. No. 4 had not failed when the experiment was terminated, other than the slight splitting referred to on April 27.

By varying the dead load in this manner it is possible to obtain the load-deflection diagram for each beam and to discover many significant points which could not be obtained were the same load kept on constantly until failure. The changes in the moisture content and consequently in the strength, due to changes in the relative humidity of the air, introduces a variable factor which greatly complicates the results, but which can not readily be avoided. During the winter the indoor humidity is frequently as low as 10 per cent., and in the hot summer when the furnaces are out it is generally above 60 and often reaches 100 per cent. The conditions of the specimens are shown by the weights of the

sample specimen and the relative proportion of the loads is estimated by means of moisture-strength curves.*

This series shows quite clearly that the immediate deflections are independent of the time effect up to the elastic limit; that an increase in moisture content may cause failure in beams which have been safely carrying a dead load; and also indicates about what relative proportion of the elastic-limit loading will produce certain effects.

The treatment of Series III is probably more readily seen from the diagram, Fig. 3, than can be explained, as a detailed explanation would be too lengthy for the present article. I will attempt, therefore, to point out merely some of the more salient features. A careful moisture record was kept of this series by weighings of the sample beam, and the moisture curve is appended to the diagram. It will be of assistance to note the following regarding the manner in which the beams were loaded: All beams were treated alike during the first 11 days, when they supported a load of 730 lbs.; Nos. 2, 3, and 4 were treated alike for 60 days, and Nos. 3 and 4 until failure. The original 730 lbs. remained on beam No. 1 until 225 days from start, deflection having ceased after 100 days. All the beams received a final load of 1,980 lbs. and all failed. Comparing with the power machine test on beam No. 6 and reducing for moisture and specific gravity, the final load of 1,980 lbs. was apparently from 70 to 80 per cent. of the ultimate strength under quick test.

After 225 days (in April) with about 8 per cent. moisture, the actual loads on the beams, the estimated proportions of the actual elastic limits, and the behavior of the beams were as follows: (The elastic limit at the time is estimated approximately by a careful study of the load-deflection diagram, and by comparison with the machine test of beam No. 6 after reducing for moisture and specific gravity. It is very difficult to determine accurately the actual elastic limits of beams under dead load.)

Beam No. 1—	730 lbs.,	44 to	47 per cent.	of elastic limit;	not deflecting.
" " 2—	1,480 "	89 "	95 "	" "	deflecting very little.
" " 3—	1,980 "	118 "	128 "	" "	still deflecting.
" " 5—	1,980 "	119 "	137 "	" "	deflecting rapidly.

* A summary of our moisture-strength researches is given in my former paper published in the Proceedings for 1907, Vol. VII, p. 582: "The Effect of Moisture and Other Extrinsic Factors upon the Strength of Wood."

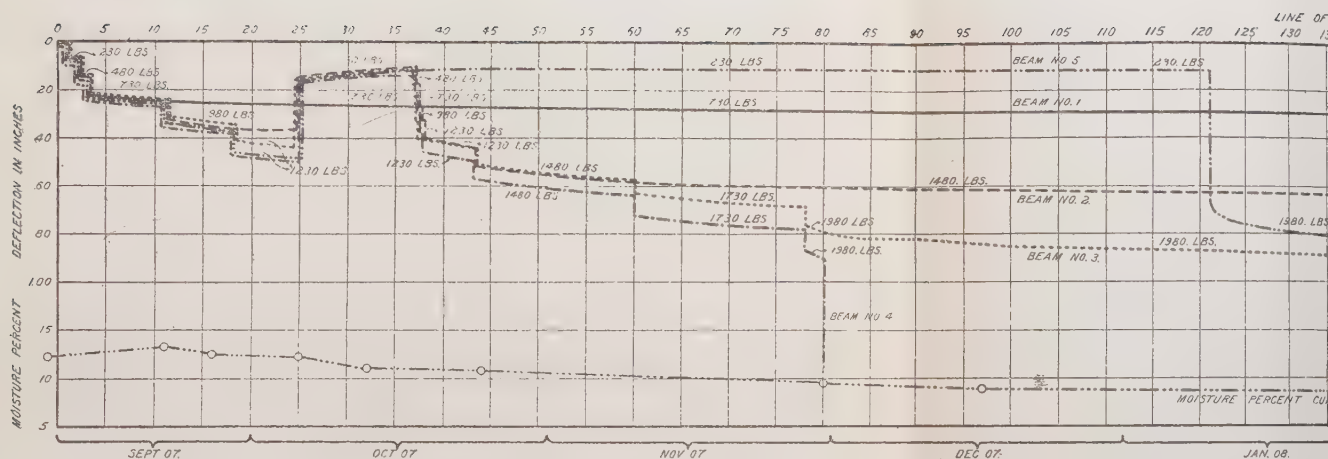


FIG. 3.—Autographic records of

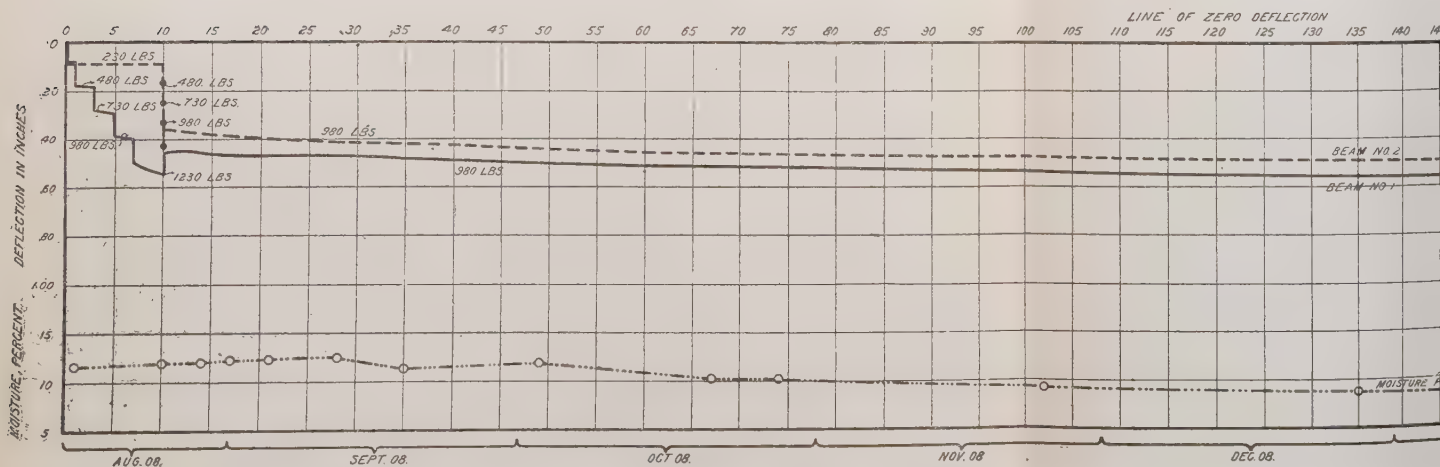
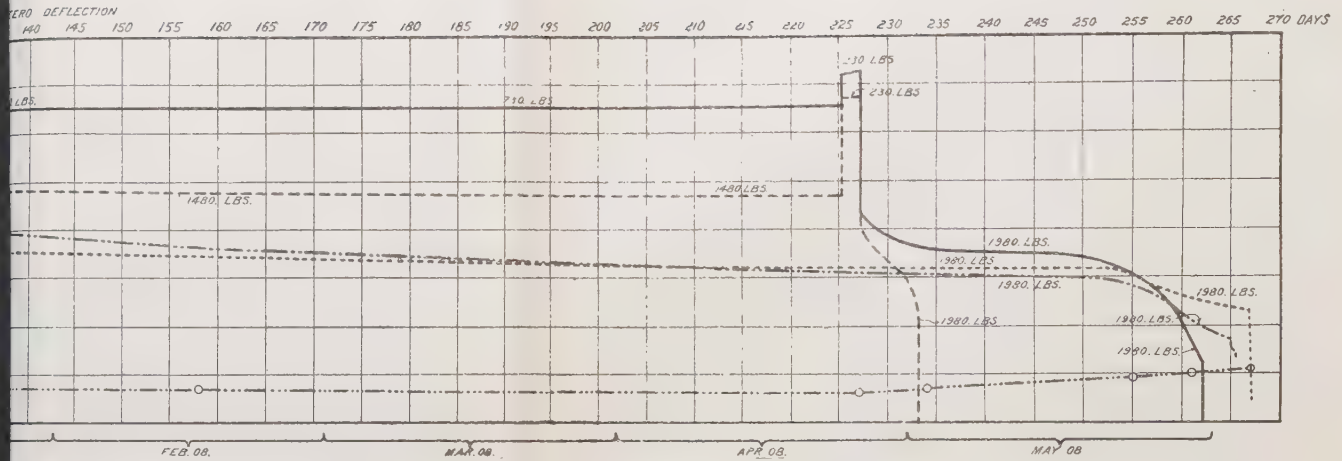
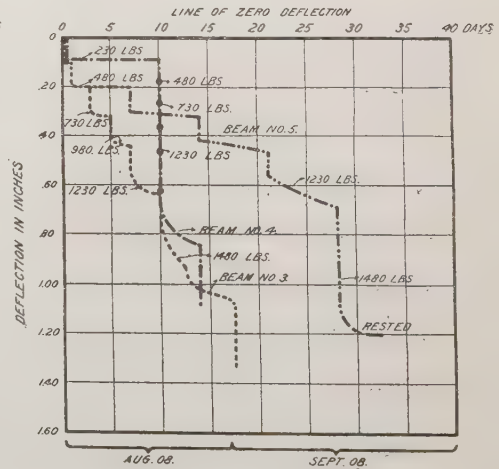
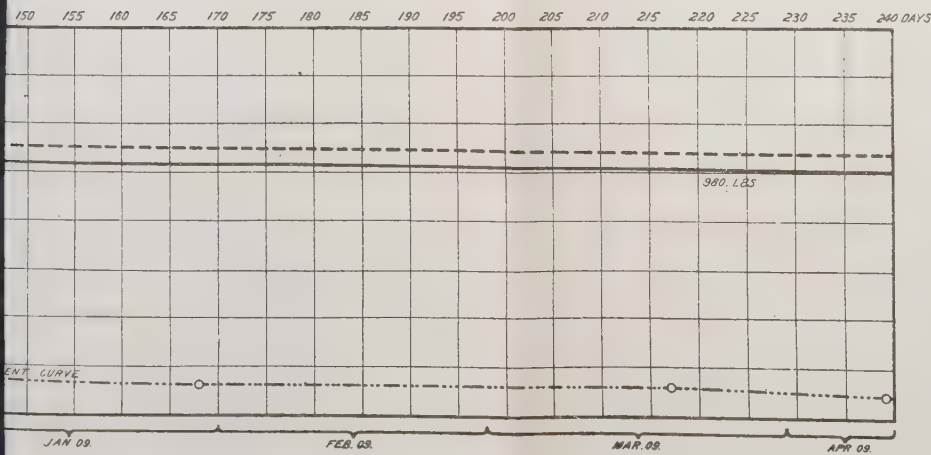


FIG. 4.—Autographic records of the five beams of Series IV. Beams Nos. 1 and 2 ceased to deflect in about 220 lbs. weight, the moisture having

PLATE IX.
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the five beams of Series III.



days at 7.5 per cent. moisture, and remained constant until about August 1, when they again began to deflect increased to over 12 per cent.

From this time on the moisture is seen to have increased quite rapidly, due to warm weather. The loads on beams Nos. 1 and 2 were then increased to 1,980 lbs., the result being rapidly increasing deflections, beam No. 2 failing in 6 days and No. 1 in 35 days. At this same time the deflections of beams Nos. 3 and 5 began to increase more rapidly, due to the increased moisture content, until they became excessive and both finally failed 267 and 265 days respectively from the start.

At the time of failure the estimated proportions of load to elastic limit were as shown in Table III.

TABLE III.

Beam No.	No. of days since first load above 230 lbs.	No. of days beam carried final load of 1,980 lbs.	Estimated proportion of final load to elastic limit at time of failure, per cent.
1	261	35	139 to 149
2	232	6	123 " 133
3	266	193	141 " 153
4	79	2	143 " 153
5	264	139	143 " 153

The most noteworthy feature of this series is shown by the load-deflection diagram, Fig. 5, in which it is quite evident from the addition and removal of the loads at various times, that the immediate deflections produced by live loads are entirely independent of the time effect of the dead loads, within the elastic limit. In these diagrams the duration of the dead load in days is indicated by small figures and the moisture content in per cent. by the figures in parentheses on the diagonals. The action of the load, whether applied or removed, is shown by the arrow heads, removal of load being indicated by the dotted lines and the second application by dash lines.

The diagram of the machine test of beam No. 6 is added for comparison. A careful study of these diagrams will reveal the fact that the elastic limit appears to have been raised by the time effect of the dead load. Beam No. 2, for example, showed on October 17 at 10.7 per cent. moisture, that the elastic limit had been passed below a load of 1,480 lbs. In fact, by comparison with beam No. 6 (reducing for moistures) it appears to be 1,300 lbs. Six months later, however, the load was removed, with the

during this time, in fact to 8.1 per cent. moisture. But according to our moisture-strength curve this should indicate an increase in the elastic limit of only 23 per cent. at most, whereas the increase shown by the diagram is 52 per cent. Other observations confirm this indication, but it can be taken only tentatively until still further evidence of the fact is obtained.

From this series of tests but little relation is shown between the load and the length of time required to break the beam. Beams Nos. 3 and 4 were loaded in exactly the same manner, yet No. 4 failed November 29, only 79 days from the start, whereas No. 3 held until the next June 4, 267 days. This comparison, however, brings out one important fact. The difference between the two beams became apparent on November 9, when No. 3 had deflected 0.05 in. during the last 17 days under a load of 1,480 lbs., while No. 4 under exactly the same conditions had deflected 0.06 in., and more significantly on November 27, when the respective deflections during the last 18 days under loads of 1,730 lbs. were 0.045 and 0.065 in. respectively, showing an actual *decrease* in the former, but an increase in the latter. This may be seen in Fig. 3. The early failure of beam No. 4 was therefore predictable. Conclusion 6 is based in part upon this observation.

In Series IV, which was started in August, 1908, an attempt was made to find out if it makes any difference in the behavior of a beam under dead load whether the load be applied by increments with periods of rest between, or applied all at once, and also the effect of loading just above or just below the elastic limit. Beam No. 1 was loaded by increments of 250 lbs. every 2 days, until the deflection showed that the elastic limit had been passed, then after 3 days, or 10 days in all, the last weight was removed, bringing the total load to within the elastic limit. On the tenth day the same load was applied to beam No. 2, but all in a few hours' time. Beam No. 3 was loaded in a similar manner to No. 1 by increments every 2 days until just past the elastic limit, but on the tenth day another weight was added, instead of removing a weight as was done in the case of No. 1. On the same day beam No. 4 was loaded to the same amount as No. 3 in a few hours' time. Thus beams Nos. 3 and 4 were supporting a load greater than their elastic limits. Beam No. 5 was loaded by increments of 250 lbs. every 7 days until it held the same load

as beams Nos. 3 and 4. All the beams, therefore, except No. 5 received their final loads on the same tenth day; the first two are still carrying their loads and have ceased to deflect, while the last three failed in a few days, as shown by the diagram, Fig. 4. The beams contained 12 per cent. of moisture at the start, and from the deflection diagram, Fig. 6, the elastic limit is seen to have been reached between loads of 1,000 and 1,100 lbs. Using these figures, the loads and their proportions to the elastic limits were as follows:

Beam No. 1—	980 lbs.,	89 to	98 per cent.	of elastic limit.				
" " 2—	980 "	89 "	98 "	" "	" "	" "	" "	" "
" " 3—	1,480 "	135 "	148 "	" "	" "	" "	" "	" "
" " 4—	1,480 "	135 "	148 "	" "	" "	" "	" "	" "
" " 5—	1,480 "	114 "	123*	" "	" "	" "	" "	" "

Beams Nos. 1 and 2 ceased to deflect in about 220 days, at which time the moisture had dried out to about 7.5 per cent.; the proportionate loading was then, according to our moisture-strength curves, only about 65 to 71 per cent. of the actual elastic limit loading, since the elastic limit had increased due to drying. The deflection remained constant until about August 1, when at 12 per cent. moisture Beam No. 2 began again to deflect slightly, as had been anticipated, due to the increase in moisture. It is still deflecting at the present time (August 28), the total increase since August 1 being about 0.015 in. The load of 980 lbs. is thus again between 89 and 98 per cent. of the original elastic limit. Beam No. 1 under exactly the same condition is behaving similarly but to a barely perceptible amount.

It appears also from these tests that periodical loading produces a greater deflection due to time effect than in the case of the load being applied all at once. Taking beams Nos. 3, 4, and 5, which were loaded beyond their elastic limit, the total deflections at failure produced by the time effect of the dead load were 0.21, 0.48, and 0.50 in. respectively, while the deflections produced by the "immediate" or live loads were practically identical, being 0.625, 0.61, and 0.60 in. respectively. The same thing is shown by beams Nos. 1 and 2, which are loaded less than their elastic limits.

* The elastic limit of No. 5 appears to be above 1,200 lbs. It is possible, however, that this higher figure may be due to a raising of the elastic limit by the time effect of the dead load, as already suggested.

Now that the beams have become stationary, the present deflections due to the time effect of dead load are 0.15 and 0.22 in., and those produced by the immediate load, 0.36 and 0.375 in., practically identical. The longer the period of loading, therefore, the greater appears to be the deflection produced.

In presenting this paper, the author has stated the

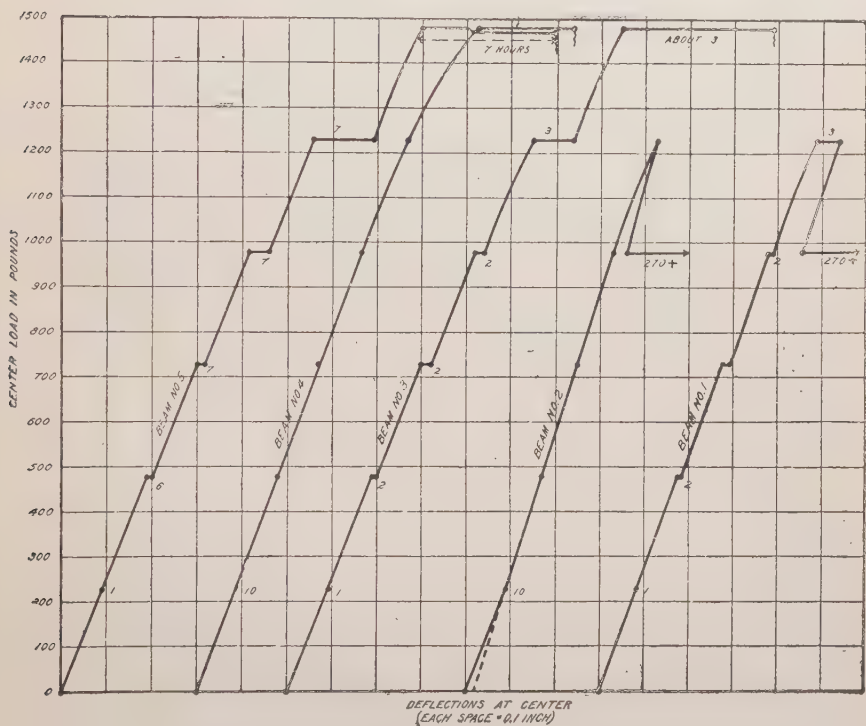


FIG. 6.—Load-deflection diagrams for the five beams of Series IV. The duration in days of the dead loads is shown by small numerals.

results with considerable reservation, fearing lest too general or hasty conclusions be deduced therefrom. The laws suggested are as yet more or less hypothetical, and are useful chiefly in indicating a working basis for further observations, and for cautious use until they can be more firmly established or disproven. The figures given, however, show at least the minimum safety limits for loading, even though future tests may show that

a wider margin exists. But the results must not be applied with too much confidence to material other than that used in these tests, namely, air-dry longleaf pine.

While the author realizes the unavoidable element of uncertainty which marks many of the deductions, he feels that the recapitulation at this time of the progress made with these dead load tests during the last three years is not without value, and in view of the number of years which must elapse, by the nature of these tests, before these deductions can be firmly established, is perhaps of more value now than a number of years hence. It would be of interest to know in the near future how the experience of other experimenters accords with the results here described. The continuation of these tests is contemplated by the Forest Service, until the fundamental laws applying to timber under time stress shall have been well established. At the present time, nevertheless, we have at least a fair indication of what may be expected to happen to timber under dead loads for various conditions, and may even predict with reasonable certainty the result in some cases.

THE EFFECT OF FREE CARBON IN TARS FROM THE STANDPOINT OF ROAD TREATMENT.

BY PRÉVOST HUBBARD.

In spite of the fact that tars have for some time been employed in the treatment and construction of roads and that the demand for road tars has greatly increased in the last few years, but little published information as to the effect of the composition upon the physical properties of these tars is to be found. Investigations along this line, if made, have probably for trade reasons remained unpublished, and for lack of information, the consumer is at a loss to know how to prepare specifications which will enable him to secure a product best suited to meet his particular requirements. Free carbon is undoubtedly one of the most variable constituents of tar, being found in quantities of from 1 to 35 per cent. and over. A study of the effect of this substance upon the properties of tars from the standpoint of road treatment should therefore be of interest to those who have occasion to employ them for this purpose.

Before taking up certain physical tests which should shed some light on this subject, it may be well to briefly consider the occurrence and origin of free carbon in tars, and it might here be mentioned that the word "tar" in this paper refers only to products obtained from the destructive distillation of coal and from the manufacture of oil gas or carbureted water gas.

If a drop of tar is examined under the microscope by transmitted light, it will be seen to consist of a more or less homogeneous liquid of a reddish brown color, in which float small black amorphous particles. It will also be noticed that the number of these particles varies enormously with different samples of tar. Under high magnification some of these particles or clumps of particles resemble irregular lumps of coal, while others are so small as to be almost sub-microscopic. If a small quantity of tar is diluted with a proper solvent such as benzol or carbon disulphide, the solution passed through a filter, and the residue which is retained upon the filter thoroughly washed with the solvent, a black

amorphous powder will be obtained, which, when examined under the microscope, can be identified as the floating particles which were found to exist in the original tar. For want of a better name this material has been called free carbon, but if a small quantity is placed upon a piece of platinum foil and ignited it will be noticed that a rather strong bituminous odor is given off, which would not occur if absolutely pure carbon were ignited.

An analysis of a powder obtained in a somewhat similar manner by Behrens* showed it to contain about 91 per cent. carbon, 3 per cent. hydrogen, and 0.4 per cent. ash. This would appear to indicate the presence of a certain amount of hydrocarbons extremely rich in carbon, and approaching the composition of those contained in anthracite coal. While such hydrocarbons may exist to some extent in tar, it would seem entirely probable, in view of our knowledge of the great absorptive capacity of amorphous carbon, that a certain amount of lighter hydrocarbons are retained by the free carbon in such a manner as to make it impossible to completely remove them by means of a solvent. In either case, however, this powder can for all practical purposes be considered as free carbon, and while the quantitative results so obtained are somewhat high in percentage values, the fact that a considerable quantity of the finest particles pass through the filter tends to make these results more nearly correct. Different solvents also remove somewhat different amounts of soluble material, so that in order to make the extraction as complete as possible the tar should be successively treated with a number of solvents. For ordinary purposes, however, the use of a single solvent is all that has been considered necessary and in this paper free carbon will be understood as material insoluble in cold carbon disulphide, minus any ash which has been found by ignition.

As to the origin of free carbon in tars, it may be said, without entering into details of the theories of the formation of tar hydrocarbons, that it is generally recognized that this material is formed at high temperatures by the splitting up or cracking of hydrocarbons formed at lower temperatures. We should therefore expect to find, and in practice actually do find, that free carbon

* *Dingler's Journal*, Vol. ccviii, p. 369.

exists in greatest quantities in those tars which have been subjected to the highest temperatures in the process of their formation. This subject has been discussed elsewhere* by the writer and need not here be considered in detail. A significant fact which should be noted, however, and which will be considered later in this paper, is that at high temperatures other products such as naphthalene and anthracene are also formed in quantities increasing with the free carbon content, so that the possible effect of their presence in high temperature tars should not be lost sight of. In general oil- and water-gas tars, although produced at the highest average temperature, are not subjected to the maximum temperatures employed in the production of coke-oven and gas-house tars. They therefore carry a low percentage of free carbon. Coke-oven tars are usually produced at considerably lower temperatures than ordinary gas-house coal tars, and therefore show a lower percentage of free carbon than the latter.

The extremely complex composition of tars and the very considerable effect upon the results obtained of slight variations in methods of testing them, makes a study of the effect of composition upon the physical properties of these products a difficult one. The selection of a proper basis of comparison for any two tars is in itself no easy matter, and due allowance for what might appear as inaccurate work in obtaining check results should be made in considering the data presented in this paper. To those who have had experience with the testing of bitumens, these facts require no further explanation. All things considered, it is believed that the uniformity of the following results is as close as could reasonably be expected.

The presence of free carbon in any considerable quantity may affect the physical properties of tars in two ways; first, either mechanically by its actual presence, or second, by the presence of other substances which were formed with it at high temperatures. To test its mechanical effect a gas house tar was selected which was found to contain 29.2 per cent. of free carbon. A quantity of this tar after dehydration was diluted with coal tar benzol and quickly filtered through a folded filter paper in order to remove most of the free carbon. The filtrate was then evaporated on a

* U. S. Department of Agriculture, Office of Public Roads, Bulletin No. 34.

steam bath beside a fresh sample of the dehydrated tar until no odor of benzol could be detected in either sample, and the evaporation continued until both samples showed the same rate of flow and approximately the same consistency as determined by the float test.

A description of this test has recently been published in a paper by Forrest,* to which paper reference should be made for complete details. In brief, it may be said to consist of a determination of the number of seconds required to sink an aluminum float carrying a standard sized plug of bitumen which has been cooled to 5° C. The plug of bitumen is held by a brass collar, which is screwed into a hole in the bottom of the float. The entire apparatus is then floated upon the surface of water maintained at a constant temperature, and as the bitumen melts water enters the float and causes it to sink. In the tests mentioned about 45 seconds were required to sink the float when placed in water at 60° C.

Determinations made upon the filtered and unfiltered tars prepared in the manner described showed them to contain 4.4 per cent. and 31.0 per cent. of free carbon respectively. By mixing proper proportions of these tars two other samples were obtained, one of which held 10 per cent. and the other 20 per cent. of free carbon. The samples were then given numbers from one to four as the free carbon contents increased. The relative cohesive or binding strength of these samples was next determined by means of a machine devised by Dr. A. S. Cushman and the writer. As this machine has not yet been perfected, its description will not be included in this paper. For the samples examined, however, it proved to be of considerable service. The results as given in Table I show the maximum resistance in pounds which was offered to a breaking load applied in tension to a layer of the tar held between two metal surfaces, the reading being obtained by means of a spring balance to which one of the metal contacts was attached. The thickness of the layer of tar was identical in every test, as well as all other conditions, such as temperature, etc., so that the results obtained are strictly comparable.

* *The Engineering Record*, Vol. 59, No. 18, p. 584.

TABLE I.

Sample No.....	1	2	3	4
Free carbon, per cent.....	4.4	10.0	20.0	31.0
Binding strength at 25° C., Test 1	18 lbs.	7.5 lbs.	4 lbs.	3 lbs.
Binding strength at 25° C., Test 2	19 "	8 "	4 "	3 "

From this table it will be seen that the cohesive or binding strength is almost inversely proportional to the amount of free carbon present. It should be remembered, however, that these tars are of approximately the same consistency, and obtained from the same source, so that this relation would not necessarily or even probably hold good for different tars of different consistencies.

While the binding strength of a tar is one of its most essential properties from the standpoint of road treatment, there are others fully as important. Its waterproofing quality when employed in a mineral aggregate should be considered, and for this purpose a number of sand-tar briquettes were made up with equal quantities of tar and their absorption in water determined.

The sand used in this and all of the other sand-tar experiments was a common river sand which had been thoroughly dried and passed through a 10-mesh sieve. It was found to contain 37 per cent. voids when consolidated, and when mechanically separated showed the following percentages of various sized grains. Its specific gravity was 2.68.

SAND.

Passing 200-mesh sieve.....	6 per cent.
" 100 " "	2 " "
" 80 " "	2 " "
" 50 " "	18 " "
" 40 " "	8 " "
" 30 " "	38 " "
" 20 " "	26 " "
	100 " "

The sand-tar mixtures were carefully prepared in metal cups heated by means of a low flame in such a manner that at all times the handle of the cup could be held without burning the hand. Very little loss by volatilization, therefore, occurred.

In the following experiments 6 parts by weight of tar were stirred with 100 parts by weight of sand, until the mixture was to all appearances absolutely uniform. While still warm the mixtures were pressed by hand into ordinary cement molds and allowed to cool. They were then removed from the mold, weighed and placed under water for 24 hours, after which they were drained free from surplus water, wiped with a soft towel and again weighed. The gain in weight was calculated upon a percentage basis as water absorbed, and the results so obtained are given in Table II.

TABLE II.

Sample No.....	1	2	3	4
Free carbon in binder, per cent. . .	4.4	10.0	20.0	31.0
Weight briquette dry, grams	111.52	110.64	109.35	109.12
Water absorbed, per cent.	3.50	4.15	6.19	10.99

It will, of course, be noticed that the percentage of water absorbed increases with the percentage of free carbon present in the binder. The same modifying factors mentioned under the binding strength tests, however, should be considered in connection with the above results.

While all of the tar samples in the preceding tests were of about the same consistency, it was realized that the actual bitumen contained could not be of the same consistency in the different samples, for the reason that if a quantity of any inert powder is added to a tar the consistency of the mixture will be greater than that of the original tar. In order to obtain some idea as to the mechanical effect of free carbon upon tar bitumens of a given consistency, a dehydrated coke-oven tar, called sample No. 5, containing 7.0 per cent. of free carbon, was selected, and to a portion of this tar lampblack was added in sufficient quantity to raise the free carbon content to 25 per cent. This mixture was called sample No. 6. The use of lampblack as a substitute for free carbon is certainly subject to criticism, but it was selected by the writer as more nearly resembling free carbon than anything else that could readily be obtained. The addition of this substance increased the consistency of the tar considerably, and determinations of the relative binding strength of the two samples made in the

manner previously described showed a considerable gain in strength for the tar to which it had been added. The results so obtained are given in Table III. These tests would seem to show that the presence of free carbon in tar bitumens of a given consistency increase the cohesive or binding strength of the material.

TABLE III.

Sample No.....	5	6
Free carbon, per cent.	7.0	25.0
Binding strength at 25° C., Test 1	13.5 lbs.	20 + lbs.
Binding strength at 25° C., Test 2	13 "	20 + "

NOTE.—Twenty pounds was the limit of the machine.

Sand briquettes were next made with these samples as in the other tests, using 6 parts by weight of tar to 100 parts by weight of sand. While the briquette made with No. 5 could be handled without breaking, that made with No. 6 would not hold together, showing that, notwithstanding the fact that the binding strength of the tar had been increased by the addition of carbon, its binding capacity had been diminished. In order to compare the relative waterproofing qualities of these two materials, it was found necessary to make a briquette with No. 6 which should have a bitumen equivalent of No. 5, and this was accomplished by using 7.44 parts of No. 6 in place of 6 parts. From the results of these absorption tests made in exactly the same manner as described in the other experiments, it will be seen that here again the percentage of water absorbed increases with the percentage of free carbon contained in the binder. These results are given in Table IV.

TABLE IV.

Sample No.	5	6
Free carbon, per cent.	7.0	25.0
Amount of binder in briquette, per cent..	6.00	6.00
Water absorbed, per cent.	1.94	Crumbled
		7.44
		3.77

When applying tar to an old road surface to insure lasting results, it is most important that the tar penetrate the surface of the road to a considerable extent. To determine the effect which free carbon would have upon this property, three coal tars containing different amounts of free carbon were selected. These tars were numbered 7, 8, and 9, in the order of their free carbon contents, and were painted upon unglazed porcelain tiles, the thickness of each coat being made as nearly the same in each case as possible. After the painted surfaces had dried, the tiles were broken and the average penetration measured. The results thus obtained are given in Table V, and indicate that free carbon seriously affects the penetrating value of tars.

TABLE V.

Sample No.	7	8	9
Free carbon, per cent.	6.7	29.2	30.9
One coat of tar, penetration, ins.	0.0625	0.0312	0.0312
Three coats of tar, penetration, ins.	0.125	0.0781	0.0781

The surface coat of bitumen was next scraped from the tiles with a knife. No. 7 was very sticky and difficult to remove. Nos. 8 and 9 could, however, be readily peeled off and the skin of bitumen thus obtained was in each case much less sticky than No. 7 and quite short.

With the exception of the tile tests all of the experiments so far described have had to do with the mechanical effect of free carbon on practically the same kind of bitumen. The fact that differences in character of the bitumens found in low and high carbon tars may affect the physical properties of the tars has already been mentioned, and in order to study the effect of both together, representative samples of low-, medium-, and high-carbon tars were taken for the following experiments. As the consistency of the tars employed in the preceding experiments was not great enough to produce sand-tar briquettes which could be successfully tested for strength, it was thought advisable to reduce these tars to the consistency of medium soft pitches, such as might be employed in road construction. While the penetration test is usually employed to determine the consistency of such materials,

the melting point as determined by the well-known cube test is generally used in grading pitches and for a number of reasons it was decided to make use of this test as a basis of comparison. In the first place, if all of the samples were found to have the same penetration at a given temperature it would not necessarily follow that they would have the same relative penetration at another temperature. Moreover, it was feared that the presence of free carbon would seriously affect the movement of the needle, so that the actual consistency of the bitumen present would not be indicated. By experiment this was found to be true at ordinary temperatures, although at low temperatures the effect of the carbon appeared to be lessened. On the other hand the melting point was believed to more nearly represent the actual consistency of the bitumen present. For the sake of comparison, however, results of both the penetration and float tests are given in Table VI.

TABLE VI.

Sample No.	10	11	12
Kind of tar	Water-gas	Coke-oven	Gas-house
Free carbon, per cent.	1.60	12.00	35.70
Melting point, degrees Cent.	50	50	50
PENETRATION TESTS.			
No. 2 needle, 5 sec., 100 gms. 25° C.—	44	50	56
No. 2 needle, next 5 sec., 100 gms. 25° C.—	16	22	24
No. 2 needle, next 5 sec., 100 gms. 25° C.—	12	17	20
No. 4 needle, 1 min., 200 gms., 50° C.	6	6	6
FLOAT TEST.			
Float test at 60° C.—time in seconds.	194	185	334

The tars selected were a Philadelphia water-gas tar, sample No. 10, a Birmingham coke-oven tar, sample No. 11, and a Providence gas-house tar, sample No. 12. Fairly large portions of these materials were evaporated in a hot-air oven until their melting points were 50° C., the temperature of the oven at no time being allowed to exceed 250° C. Sand-tar mixtures with varying proportions of binder, as shown in Tables VII and

VIII, were then made up, and these mixtures molded into briquettes in the following manner:

Twenty grams of the mixture were weighed out and placed in a cylindrical metal mold carrying a close fitting plunger. Pressure was then applied by means of a small Olsen testing machine run at a constant speed. All of the mixtures were subjected to a pressure of 1,425 lbs., and the briquettes thus formed measured 25 mm. in diameter and approximately 25 mm. in height. There was no particular reason for making the briquettes in just this manner, except that the method conformed to the general method employed by the Office of Public Roads in making rock dust briquettes for the cementation test.

As soon as they were made, three briquettes of each mixture were placed in a refrigerator for 30 minutes, after which they were immersed in ice water at 5° C. for 30 minutes and tested under water at this temperature in the Olsen testing machine, which was run at a definite speed. Tests were made in compression, and the maximum resistance offered by the briquettes noted. Check tests on the same mixtures varied somewhat, as shown in Tables VII and VIII, but it is believed that a comparison of the average results will prove of considerable value in determining the effect of free carbon upon the binding values of the tars. Slight variations in the method of making the tests were found to cause considerable variations in results, so that it was necessary to take every precaution to exactly duplicate the conditions under which each of these tests were made.

Tables VII and VIII are self-explanatory, so that it seems unnecessary to describe them further than to say that two series, one with 6 per cent. binder and the other with 10 per cent. binder, were made in such a manner that comparisons upon both a percentage binder and maximum and minimum percentage bitumen basis could be drawn. In these briquette tests the percentage of all constituents is based upon the weight of sand taken as 100.

In considering the compression tests in Table VII, it will be seen that for equal quantities of binder the low-carbon tar has a greater binding strength than either of the others, and that the medium-carbon tar gives higher results than the high-carbon tar. For equal quantities of bitumen on the basis of the minimum amount present, as shown by No. 12, the results are nearly the same

TABLE VII.

Sample No.	Comparative Basis.	Per cent. Tar.			Maximum Per cent. Bitumen.			Minimum Per cent. Bitumen.		
		IO	II	I2	IO	II	I2	IO	II	I2
Free carbon, per cent.		1.60	12.00	35.70	1.60	12.00	35.70	1.60	12.00	35.70
Per cent. " tar in briquette.		6.00	6.00	6.00	6.00	6.70	9.17	3.93	4.39	6.00
" " bitumen in briquette.		5.90	5.28	3.86	5.90	5.90	3.86	3.86	3.86	3.86
" " carbon in briquette.		0.10	0.72	2.14	0.10	0.80	3.27	0.07	0.53	2.14
Compressive strength in lbs. (1) ..		*308	†377	†442	*398	*470	†619	†184	†146	†142
" " " (2) ..		*373	*345	†223	*373	*465	†617	†150	†106	†223
" " " (3) ..		*300	*355	†138	*300	*451	†592	†152	†200	†138
" " " (average) ..		377	359	168	377	464	609	104	181	168
Per cent. water absorbed, 48 hours.		5.44	5.24	7.55	5.44	5.28	5.58	6.66	6.44	7.05

*Briquette was deformed but not broken by maximum load.

†Briquette was broken by maximum load.

‡Briquette crumbled under maximum load.

TABLE VIII.

Sample No.	Comparative Basis.	Per cent. Tar.			Maximum Per cent. Bitumen.			Minimum Per cent. Bitumen.		
		IO	II	I2	IO	II	I2	IO	II	I2
Free carbon, per cent.		1.60	12.00	35.70	1.60	12.00	35.70	1.60	12.00	35.70
Per cent. " tar in briquette.		10.00	10.00	10.00	10.00	11.18	15.30	6.53	7.31	10.00
" " bitumen in briquette.		9.84	9.84	9.84	9.84	10.84	15.84	6.43	6.43	0.43
" " limestone dust in briquette.		0.16	0.16	0.16	0.16	1.34	5.46	0.10	0.88	3.57
" " total filler in briquette.			5.30	.....	.....	4.16	.....	3.47	.....	0.00
Compressive strength in lbs. (1) ..		760	630	760	838	842	772	446	620	630
" " " (2) ..		705	691	648	795	786	768	416	402	683
" " " (3) ..		740	648	645	790	804	710	423	483	645
" " " (average) ..		735	682	644	755	806	750	428	608	644
Per cent. water absorbed, 48 hours.		4.05	3.93	4.95	3.67	2.66	2.77	4.34	4.02	4.25
Per cent. volatilization, first 5 hrs. 100° C.		2.52	3.69	6.43	.....	.....	5.22	4.23	.....	4.43
" " " second 5 hrs. 100° C.		1.08	1.27	1.92	1.15	.....	1.32	0.95	.....	1.70
" " " third 5 hrs. 100° C.		0.86	1.15	1.95	1.03	.....	1.09	1.35	.....	1.02
" " " fourth 5 hrs. 100° C.		1.04	1.10	1.45	1.03	.....	1.07	1.66	.....	1.23
" " " 20 hours. 100° C.		5.50	7.30	10.15	5.50	.....	8.70	7.99	.....	10.15

NOTE.—In the compression tests all of the briquettes were deformed but not broken by maximum load. Loss by volatilization is given upon the basis of bitumen present in the briquette.

for all of the tars. Upon a maximum bitumen basis as shown by No. 10, the results are, however, reversed. The explanation for this lies in the fact that when considerable quantities of free carbon are present, the carbon acts as a filler and adds to the mechanical strength of the mineral aggregate. This is shown in Table VIII under the heading "Minimum Per Cent. Bitumen," in which the percentage of bitumen is almost the same as in the last tests mentioned in Table VII. It will, however, be noticed that where limestone dust is added in sufficient quantity to produce an equivalent weight of filler, the strength developed by the same percentage of bitumen is again almost the same for the different tars. This is an important consideration from the standpoint of road construction.

In Table VIII, where an equivalent amount of binder is employed, it will be seen that the same general relations hold good as shown under similar conditions in Table VII. The differences are, however, not so marked, because of the more prominent part played by free carbon as a filler. It should be remembered, however, that in ordinary bituminous macadam construction, more than 6 per cent. of bitumen is seldom employed in the mineral aggregate, and that as this aggregate is much coarser than the sand used in the tests, the action of the relatively small amount of carbon as a filler is hardly worth considering. The results given in Table VIII under the heading "Maximum Per Cent. Bitumen" would tend to show much the same thing as the "Minimum Per Cent. Bitumen" tests, although here the high-carbon tar shows up to even less advantage. Considered as a whole, these tests show the mechanical effect of free carbon but would not seem to indicate that the bitumen present in low- and high-carbon tars varies greatly in binding value.

Absorption tests made upon these briquettes show in both Tables VII and VIII that where equivalent quantities of binder are employed, those briquettes which are made with the high-carbon tar are somewhat less waterproof than the lower-carbon tars. In Table VII the same general relations seem to hold good for the maximum and minimum bitumen tests, but in Table VIII, in the bitumen equivalent tests, the excess of bitumen-coated carbon seems to have lowered the absorptive capacity of the briquettes. A still further lowering is, however, observed where

limestone dust has been added in the briquettes made with low-carbon tars, and the superiority as a filler of limestone over carbon is again indicated. In considering these tests as a whole it might be remarked that a slight superiority in waterproofing power of the bitumens contained in No. 11 over the other tars is indicated, although this difference is by no means great.

One other important property of tars from the standpoint of road treatment which has not yet been considered is the relative amount of volatilization which may be expected to take place on a tar-treated road. Some of the constituents of all tars will volatilize at ordinary temperatures, thus making the residue more and more brittle and lessening its life. It is believed by some that the presence of free carbon retards this volatilization, and the reason for this belief lies in the fact that in both evaporation and distillation tests a film of carbon forms upon the surface of the hot tar and retards to a considerable extent the volatilization of the lighter constituents. In evaporating the three tars which were employed in all of the later tests, this effect was made very evident by the time required to bring No. 12 to the proper consistency as compared with that necessary to bring the other samples to the same consistency. When tar is employed in road work, however, conditions are somewhat different, for here the tar does not exist in thick layers, but is distributed over the surface of the particles composing the mineral aggregate in comparatively thin films.

In order to determine whether or not free carbon retards volatilization under these conditions, it was thought well to subject some of the sand-tar briquettes to a volatilization test. Briquettes composed of different mixtures were therefore carefully weighed upon watch glasses and placed in a hot-air oven maintained at a uniform temperature of 100° C., for four consecutive periods of 5 hours each. The loss in weight for each period was determined and the percentage loss upon the basis of bitumen present calculated. The results thus obtained are given in Table VIII. The first fact to be noted is that the greatest loss in every case occurred during the first period, and that the greatest differences between individual tests are made apparent here. During the next three periods the loss by volatilization seems to be practically a constant and quite uniform for the different briquettes. In the first period it will be noticed that the higher the percentage of free

carbon the greater the loss by volatilization, and if these results alone were considered one might naturally come to the conclusion that the presence of free carbon increased the volatility of the tar. In view of the general uniformity of the next three tests, however, this opinion would have to be modified and the only reasonable conclusion would seem to be that under the given conditions free carbon is mechanically inert as far as volatilization is concerned. It would seem, however, that in tars of the same melting point the percentage of highly volatile constituents increases as the percentage of free carbon increases, and that a greater loss by volatilization would occur in high-carbon tar than in low-carbon tars under conditions encountered in tar-treated roads. That the thickness of the tar film has considerable effect upon the volatility of the tar is indicated by the fact that in nearly every case less loss by volatilization occurred in the maximum bitumen tests than in the corresponding minimum bitumen tests. In this connection it might be said that one of the advantages of employing a flush coat of tar in bituminous road construction is made apparent, as a coat thus applied retards the volatilization of the thinner underlying films of tar and therefore prolongs the life of the road.

Before summarizing the results of the experiments presented in this paper, it may be well to mention one other property of tars and its possible relation to the free carbon content; i. e., the relative susceptibility to temperature changes shown by bitumens contained in different tars. Owing to the fact that free carbon, if present in any quantity, seriously interferes with a correct determination of the consistency of the accompanying bitumen, it would seem necessary to completely remove the carbon before attempting to determine the susceptibility of the bitumen to temperature changes. Since such bodies as naphthalene and anthracene, which crystallize at comparatively high temperatures, usually occur in greater quantities in high-carbon than in low-carbon tars, it would seem reasonable to suppose that the bitumen obtained from the former would be more susceptible to temperature changes. This is an important point to be determined and one which the writer proposes to investigate. As it is only indirectly related to the subject of this paper it will not be further discussed at this time.

Upon reviewing all of the results presented in this paper it is believed that the following facts have been demonstrated with respect to the effect of free carbon in tars:

1. That in tars of the same consistency, those of low-carbon content have a greater inherent binding strength than those of high-carbon content.

2. That in tars whose bitumen contents are of the same consistency, those of high-carbon content have a greater inherent binding strength than those of low-carbon content, but that the binding capacity of the former is lower.

3. That in sand-tar mixtures containing a relatively large amount of high-carbon tar, the carbon may act as a filler and add to the mechanical strength of the mineral aggregate, but that better results in this respect can be obtained by the use of a smaller quantity of low-carbon tar of the same melting point, together with a mineral filler.

4. That the waterproofing value of high-carbon tars is in general less than that of low-carbon tars.

5. That free carbon retards the absorption of tars by porous surfaces.

6. That when tar is exposed in comparatively thin films, free carbon has little or no effect in retarding volatilization.

Applying these facts to the use of tar in road treatment, the following conclusions are logically deduced:

1. In the treatment of old road surfaces a low-carbon tar is greatly to be preferred to a high-carbon tar.

2. In ordinary bituminous road construction, both from the standpoint of efficiency and economy, a low-carbon tar is to be preferred to a high-carbon tar whose bitumen content is of the same consistency.

In conclusion it might be said that to the writer's knowledge no reliable comparative data as to the actual service results obtained by the use of high- and low-carbon tars in road work are at present available. A road engineer in one locality may have obtained more satisfactory results from the use under certain conditions of a high-carbon tar of a certain consistency, than another engineer in a different locality using a low-carbon tar of different consistency under different conditions, and vice versa. Many other factors besides the free carbon content have to be

considered in forming a correct opinion of the relative value of two tars.

The writer also realizes that laboratory results do not always conform to actual service results, but they are nevertheless often of considerable value to those who are studying a subject from a practical standpoint. The Office of Public Roads is doing this both in the laboratory and in the field, and I might add that service results so obtained seem to substantiate the general conclusions presented in this paper.

DISCUSSION.

MR. S. R. CHURCH.—The more experience one has with tars, the more difficult it becomes to classify them in the way that Mr. Hubbard has been obliged to do from the nature of those tests. As I understand it, Mr. Hubbard's tests were made with three samples of tar of the minimum, medium, and maximum percentage of free carbon. All these tests were made, I understand, with the same three samples of tar. Now what holds true with these three samples, as is evident from the carefully prepared tables, might not hold true with other samples produced under different conditions yet having approximately the same percentage of free carbon. For instance, Mr. Hubbard has stated that in his opinion the formation of free carbon with high heats is usually accompanied by a large percentage of naphthalene and other crystallizable compounds of tar. I have seen tar which contained a very large percentage of naphthalene, attended by a low percentage of free carbon, 8 per cent. in fact; so that it becomes apparent to those who have examined a great many tars that it is extremely difficult to classify them in this way. Mr. Church.

Again, in connection with Table II of Mr. Hubbard's paper, the addition mechanically in the laboratory of an inert filler to take the place of free carbon, thus bringing the resulting product up to any given percentage of free carbon, yields a tar which is quite different in its other physical properties from a tar that naturally contains a like percentage of free carbon. We have determined that fact on a large scale in our stills by adding free carbon or the equivalent of free carbon, and we found that the evaporation test of the resulting product, that is, of the synthetic tar if you wish to call it that, gave a very much higher result than the evaporation test of tar containing an equal amount of free carbon produced in the actual manufacture of the tar. I merely mention these things to show how complex the subject is, and the danger of forming too radical opinions on the basis of a set of tests made with one series of tar compounds.

Mr. Hubbard.

MR. P. HUBBARD.—I realize that what Mr. Church says is perfectly true. It is an extremely complicated subject. These results are only given for what they are worth as laboratory tests. With regard to my experimental data I would say that Mr. Church is mistaken in thinking that only three tars were used. In the first five tables there were some eight or nine different tars; in the last two tables the same three tars were employed for the purpose of obtaining a better basis of comparison. I also realize that naphthalene and anthracene are sometimes found where free carbon exists in small quantity, depending to a great extent upon the character of the original coal, but as a rule naphthalene and anthracene are found in high-carbon tars to a greater extent than in low-carbon tars.

Mr. Blanchard.

MR. A. H. BLANCHARD.—In connection with the results of Mr. Hubbard's experiments, it may be of interest to note that the free carbon content of the coal-gas tar from the Providence Gas Co., which is used in the construction of bituminous macadam roads in Rhode Island, is high, the average being about 28 per cent.

Bituminous macadam roads have been built in the state highway system of Rhode Island since 1906. All the roads have been constructed by the mixing method with the exception of some experimental sections laid in 1908. The bituminous material used has been mainly crude tar obtained from the Providence Gas Co. and Texaco asphalts. The bituminous macadam roads built with the crude tar as the bituminous binder in 1906 and 1907 are apparently in as good condition to-day as when laid.

Mr. Hubbard has referred to certain service tests which he believes confirm his laboratory experiments. I think information relative to the service tests would prove interesting to the Society.

Mr. Hubbard.

MR. HUBBARD.—The first test which I have in mind was made at Jackson, Tenn., where a coke-oven tar containing approximately 10 per cent. of free carbon was employed; also certain work at Birmingham, Ala., where the roads were constructed according to the Warren Brothers' specifications, with the same low-carbon tar. At Wayland, Mass., in 1907, sections of an old macadam road surface were treated with medium-carbon tars and also with a high-carbon tar, the results with the former being much more satisfactory than with the latter. From the latest reports of work carried on last summer at Newton,

Mass., to which possibly Mr. Blanchard refers, the use of a refined water-gas tar as a binder proved very satisfactory in comparison with asphalt and oil preparations. This tar contained about 5 per cent. of free carbon. Mr. Hubbard.

MR. CHURCH.—In the treating of roads there are two distinct methods, or perhaps it would be more correct to say that there are two classes of treatment; one consists of the application of tar or any other compound essentially as a dust preventative, and the other of the use of a bituminous compound as a binder either in building a new road or re-surfacing an old one. I think it would add greatly to the value of these references to roads that are now being mentioned if the speakers would state whether the material was added merely as a surface treatment or whether it was used in building up the concrete. Mr. Church.

MR. HUBBARD.—At Jackson, the work was purely surface treatment. The work that I referred to in Massachusetts was partly surface treatment and partly construction. At Birmingham it was all construction work. Mr. Hubbard.

MR. JAMES W. HOWARD.—I went to France and examined some tarred roads in the Vendée District. I found the French engineers referred in all their tests to the qualities of the bitumen contained in the tar, and regarded extraneous matter, such as free carbon and other materials, as something that unfortunately accompanied tars. When there was a large amount they made up for the presence of such extraneous matter by increasing the quantity of special refined tar used. Therefore, they determined first, the quality of the bitumen in the tar for adhesion and other properties, and second, the amount of the bitumen calculated at a certain percentage of the tar to be used. That road was laid in 1896 and it cost about 41 per cent. less than the taxes required to maintain the previous road for the preceding ten years when it was simply macadamized. It is a successful experiment the details of which are published by the Government and can be obtained by writing to the Engineer of the Vendée District. Mr. Howard.

IMPROVED INSTRUMENTS FOR THE PHYSICAL TESTING OF BITUMINOUS MATERIALS.

BY HERBERT ABRAHAM.

AN INSTRUMENT FOR ASCERTAINING THE HARDNESS OF BITUMINOUS MATERIALS.

Instruments in Use.—In a paper read before this Society,* Richardson and Forrest reviewed a number of instruments for ascertaining the consistency of plastic substances. These included two well-known forms; namely, the Bowen and the Dow penetrometers, together with one devised by the authors of the paper. The underlying principle of these three instruments is virtually the same. A weighted needle is allowed to act on the material under examination for a definite period of time, at a prescribed temperature, and the depth to which it penetrates is recorded by means of a suitable measuring device. Five factors are therefore involved, four constants and one variable. The size and shape of the needle, the weight applied, the temperature and the interval of time are fixed and definite quantities in any particular test, whereas the distance penetrated is allowed to vary, and is regarded as an indication of the consistency of the substance examined.

In the three instruments referred to, the following factors have been selected:

Penetrometer.	Constants.				Variable.
	Needle.	Weight, grams.	Temperature, degrees F.	Time, seconds.	Penetration.
Bowen.....	No. 2 sewing.	Arbitrary.	77	1	Recorded in circular degrees.†
Dow and Richardson-Forrest }	"	200	32	60	Expressed in hundredths of a centimeter.
	"	100	77	5	
	"	50	100	5	

* "The Development of the Penetrometer as Used in the Determination of the Consistency of Semi-Solid Bitumens," by Clifford Richardson and C. N. Forrest. Vol. VII., pages 626-31.

† 360° correspond to ¼ in. penetration.

Short-comings of these Penetrometers.—The shape of a No. 2 sewing needle is purely arbitrary, and does not readily admit of duplication. Its exact size, moreover, varies considerably. In a single package examined by the writer, the needles varied in weight from 0.2648 to 0.2807 grams, or 6 per cent. As all the needles were substantially of the same length, i. e., 4.8 cms., this variation must have largely affected their cross section.

The total work performed in effecting a penetration is equal to that expended in displacing the plastic solid, plus that used in overcoming the frictional adhesion of the substance in contact with the surface of the needle. When a pointed needle is used, both the volume displaced and the frictional adhesion increase proportionately very much more rapidly than the corresponding depth of penetration. In successive time intervals the increments do not follow any definite law. The depth of penetration of a pointed needle is not, therefore, a true measure of the hardness.

The range of a No. 2 sewing needle acting under a fixed weight is found in practice to be limited. If the weight actuating the needle be very great, its sensitiveness for soft materials becomes sacrificed. If a relatively small weight be employed, the needle will on the other hand fail to penetrate hard substances. If, as in the case of the Dow instrument, a number of weights are employed to extend its effective range, two variables are introduced and the different sets of readings cannot be compared. If the time element is likewise varied, as is actually done under certain conditions, the sets of readings are rendered still more complex and empirical.

The Consistometer.—To obviate these difficulties an instrument was constructed, which was planned to operate upon strictly scientific principles, so that the readings might form an accurate indication of the true hardness, and at the same time be capable of practically an unlimited range of action.

This was accomplished by using a special form of needle and applying a weight sufficient to cause it to penetrate at a certain definite and *uniform rate*. Instead of applying a fixed weight and recording the distance penetrated, as was done in the previous instruments, the procedure was simply reversed. In the consistometer, the rate of penetration is maintained constant, and the weight applied made the variable factor. Inasmuch as the weight

may be increased or decreased without limitation, the effective range of the instrument may be extended proportionately. After a series of experiments, it was found that a needle having a round flat head and a reduced shank gave the best results. This form, moreover, is capable of being duplicated at any time without difficulty. On account of the reduced shank the frictional ad-

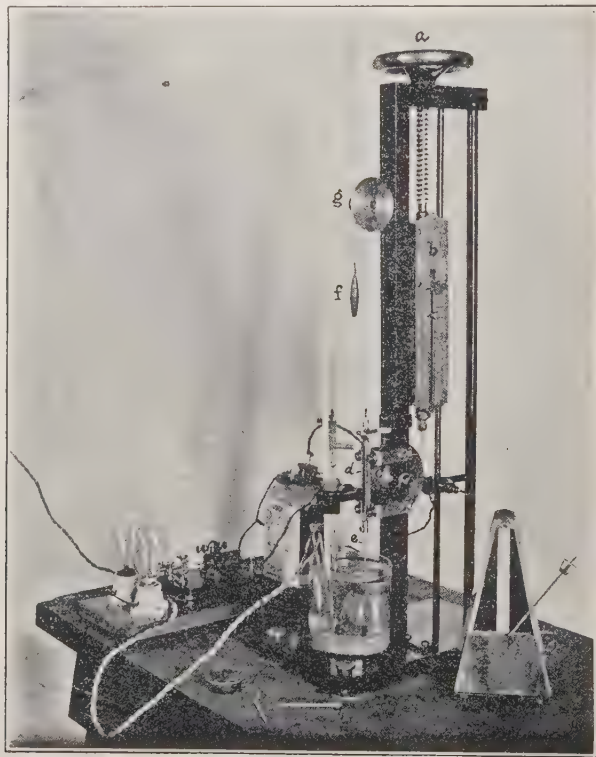


FIG. 1.

hesion of the material is localized to the flat head, and remains uniform throughout the entire operation. The flat head may readily be brought in contact with the surface of the bituminous material without requiring any particular skill, or incurring danger of introducing an error through faulty adjustment. The greatest advantage of this procedure, however, is due to the fact that,

inasmuch as identical volumes of material are displaced in every determination, the weight applied forms a true measure of the hardness of the material examined. These principles were found to work out in practice just as nicely as they appeared in theory.

The apparatus is shown in Fig. 1. It consists of a hand-wheel *a* attached to a spring balance *b* reading to tenths of a kilogram, and equipped with both maximum and continuous reading indicators. A flexible copper wire passes from the balance around a grooved wheel *c* and is attached to a yoked spindle *d* carrying the needle *e*. The spindle has two knife edges operating on roller bearings to reduce the friction to a minimum. The spindle is counterbalanced by a weight *f* and is connected with a dial *g*, graduated in sixths of a centimeter.

The sample to be tested is supported in a small reservoir filled with water and maintained at a constant temperature of 77° F. by means of a heating coil connected with incandescent lamps in series, which in turn are controlled by a mercury thermostat working in conjunction with a relay. This contrivance in practice actually prevents the temperature fluctuating more than about $\frac{1}{2}^{\circ}$ F. The heating coil may be used to maintain the temperature of the water at either 77° or 100° F. as desired. For testing the sample at 32° F., finely chopped ice or snow is recommended.

After the sample has been brought to the desired temperature, the needle is lowered to contact with its surface and the pointer on the dial *g* moved to the zero mark. The pressure is then applied by operating a hand wheel so as to cause the needle to penetrate the substance at the definite speed of one centimeter in exactly 60 seconds. The time is taken from a metronome with a bell attachment, and the speed controlled by following the pointer on the dial *g*. At the termination of 60 seconds, the pressure is relieved and the reading of the maximum hand on the balance *b* noted.

I find that when the needle commences to penetrate at the specified speed of one centimeter per minute, a maximum reading is obtained, which remains fairly constant throughout the penetration. Three needles have been adopted as follows:

	No. 1.	No. 2.	No. 3.
Diameter of head. . .	1.13 mm.	3.56 mm.	11.28 mm.
Area of head.	0.01 sq. cm.	0.1 sq. cm.	1.0 sq. cm.

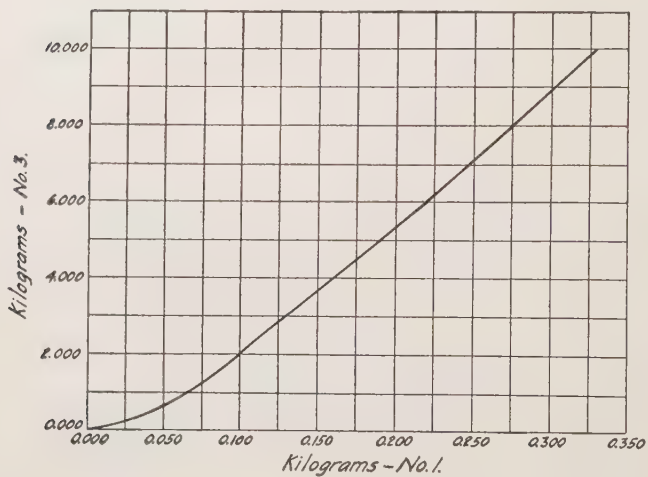


FIG. 2.

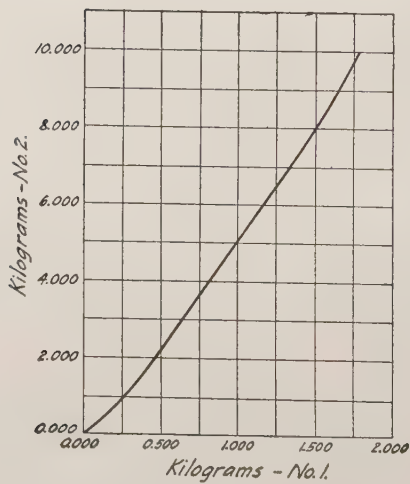


FIG. 3.

I have carefully worked out the relations between these three needles, and for the sake of uniformity express all readings in terms of needle No. 1. Figs. 2 and 3, plotted from a large number of determinations, show the relations between the needles.

Upon first using the apparatus it became apparent that for substances of varying hardness the readings increased proportionately very much more rapidly than would be judged by such physical tests as chewing, etc. The fact was thereupon discovered that the *square root* of the number of grams applied corresponds closely to the hardness as it appears to the senses. All readings, therefore, are expressed as the square root of the number of grams which must be applied to a round, flat surface 0.01 sq. cm. in area, so as to cause it to penetrate to a distance of one centimeter in exactly one minute. This figure is termed the "hardness" of the material.

The readings conveniently form a scale of "hardness" expressed in "degrees" ranging from 0 to 100. The highest figure on the scale, 100, is equivalent to 10,000 grams applied to needle No. 1. This is equivalent in round numbers to 14.2 tons per sq. in. and is found to be more than sufficient to penetrate the hardest plastic substance ordinarily encountered.

The following figures will convey some idea as to the range of this scale:

Vaseline	0.3	degrees	hardness	at	77° F.
Commercial D-grade asphaltum . .	16.0	"	"	"	"
Paraffine wax	23.7	"	"	"	"
Ozokerite	43.6	"	"	"	"
Gilsonite No. 1	94.3	"	"	"	"

Table I shows the relation between the consistometer readings in kilograms and the "degrees hardness," all the results being expressed in terms of needle No. 1.

Of course for very soft substances, where a greater degree of sensitiveness is required, the spring balance reading to tenths of a kilogram may be readily replaced by a balance reading to grams. The underlying principle, however, remains the same.

The only particular skill required in using the apparatus consists in maintaining a uniform rate of penetration. Even this does not influence the readings as largely as might be expected, as will appear from the following figures:

Rate of Penetration.				Kilograms.	Degrees,	Incre-
				Needle No. 2.	Hardness.	ments.
1	cm. per	240	seconds.....	2.00	21.20	4.05
1	" "	120	"	3.05	25.25	3.90
1	cm. per	60	seconds.....	4.25	29.15	4.00
1	" "	30	"	5.60	33.15	3.95
1	" "	15	"	7.20	37.10	

It is interesting to note that by increasing the speed of penetration according to a geometrical progression, the hardness is caused to vary in an arithmetical progression.

The Consistometer may likewise be employed to determine the "elasticity" or "resilience" of bituminous materials. This is accomplished by immediately releasing the load after the needle has penetrated to the depth of one centimeter. The rebound of the material is recorded by the pointer on the dial *g*, which then travels in a reverse direction. The reading is noted at the termination of exactly one minute, and is expressed in centimeters. In practice I find that equilibrium is usually re-

TABLE I.—FOR CONVERTING CONSISTOMETER READINGS INTO DEGREES HARDNESS.

Kilos. Applied	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
<i>Needle No. 3:</i>										
0.....	0.0°	3.2°	4.5°	5.4°	5.9°	6.3°	6.7°	7.1°	7.5°	7.8°
1.....	8.1	8.35	8.6	8.8	9.0	9.2	9.4	9.55	9.7	9.85
2.....	10.0	10.15	10.3	10.45	10.6	10.75	10.9	11.0	11.2	11.35
3.....	11.5	11.65	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5
4.....	12.6	12.7	12.8	12.9	13.0	13.1	13.2	13.3	13.4	13.5
5.....	13.6	13.7	13.8	13.9	14.0	14.1	14.2	14.3	14.4	14.5
6.....	14.6	14.7	14.8	14.9	15.0	15.1	15.2	15.3	15.4	15.5
7.....	15.6	15.7	15.8	15.9	16.0	16.1	16.2	16.3	16.4	16.5
8.....	16.55	16.6	16.7	16.8	16.85	16.9	17.0	17.1	17.2	17.3
9.....	17.35	17.4	17.5	17.6	17.7	17.8	17.9	17.95	18.0	18.1
<i>Needle No. 2:</i>										
1.....	16.1	16.75	17.3	17.9	18.5	19.0	19.4	19.75	20.25	20.75
2.....	21.2	21.7	22.1	22.6	23.0	23.25	23.7	24.0	24.3	24.7
3.....	25.0	25.5	25.9	26.2	26.5	26.8	27.2	27.5	27.8	28.2
4.....	28.5	28.7	29.0	29.3	29.7	30.0	30.25	30.5	30.8	31.1
5.....	31.5	31.7	32.0	32.25	32.5	32.8	33.15	33.4	33.6	33.9
6.....	34.2	34.5	34.8	35.0	35.2	35.5	35.7	35.9	36.2	36.4
7.....	36.6	36.8	37.1	37.3	37.5	37.7	37.9	38.1	38.3	38.5
8.....	38.7	38.9	39.1	39.4	39.6	39.75	40.0	40.2	40.4	40.6
9.....	40.8	41.0	41.2	41.4	41.6	41.8	42.0	42.2	42.4	42.5
<i>Needle No. 1:</i>										
1.....	31.6	33.2	34.6	36.1	37.4	38.7	40.0	41.2	42.4	43.6
2.....	44.7	45.8	46.9	48.0	49.0	50.0	51.0	52.0	53.0	53.9
3.....	54.8	55.7	56.6	57.5	58.4	59.2	60.0	60.8	61.6	62.45
4.....	63.25	64.0	64.8	65.6	66.3	67.1	67.8	68.6	69.3	70.0
5.....	70.7	71.4	72.1	72.8	73.5	74.2	74.8	75.5	76.2	76.8
6.....	77.5	78.1	78.7	79.4	80.0	80.6	81.2	81.85	82.5	83.1
7.....	83.7	84.3	84.85	85.4	86.0	86.6	87.2	87.75	88.3	88.9
8.....	89.4	90.0	90.55	91.1	91.65	92.2	92.7	93.3	93.8	94.3
9.....	94.9	95.4	95.9	96.4	96.95	97.5	97.9	98.5	99.0	99.5
10.....	100.0	100.5	101.0	101.5	102.0	102.5	103.0	103.4	103.9	104.4

established at the end of this period, and also that for any particular material the size of the needle employed does not appear to affect the result.

Comparison of the Consistometer with the Dow Penetrometer.—Table II shows the relation between the “degrees hardness” (consistometer) and the Dow penetrometer readings. This will give some idea of the range and relative sensitiveness of the two instruments.

TABLE II.—SHOWING RELATION BETWEEN THE CONSISTOMETER
(DEGREES HARDNESS) AND THE DOW PENETROMETER
(HUNDREDTHS OF A CENTIMETER).

No. 2 Sewing Needle; Weighted with 100 grams; Acting 5 seconds.

Degrees	0	1	2	3	4	5	6	7	8	9
10	70.0	60.4	52.4	44.8	39.5	34.5	30.7	27.7	25.7	
20	21.7	20.0	18.4	17.0	15.7	14.5	13.5	12.7	12.0	
30	10.5	9.8	9.2	8.6	8.1	7.6	7.1	6.7	6.3	
40	5.7	5.4	5.1	4.8	4.6	4.4	4.2	4.1	4.0	
50	3.9	3.7	3.5	3.4	3.2	3.1	3.0	2.9	2.8	
60	2.5	2.3	2.2	2.1	2.0	1.9	1.85	1.8	1.7	
70	1.6	1.5	1.5	1.4	1.4	1.3	1.25	1.2	1.2	
80	1.25	1.0	0.9	0.8	0.75	0.7	0.65			

Shaft 3.175 mm. diameter, having a 30° Conical Point; Weighted with 50 grams;
Acting 5 seconds.

Degrees	0	1	2	3	4	5	6	7	8	9
10	731.0	481.0	315.0	207.0	138.0	94.0	66.0	48.0	37.4	
20	30.7	26.6	23.7	21.1	19.0	17.1	15.3	14.0	12.8	
30	10.6	9.7	8.9	8.1	7.4	6.8	6.3	5.8	5.4	
40	4.8	4.5	4.2	4.0	3.8	3.6	3.4	3.2	3.1	
50	2.8	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2.05	
60	1.95	1.9	1.8	1.8	1.7	1.65	1.6	1.5	1.45	
70	1.3	1.2	1.2	1.1	1.1	1.0	1.0	1.0	0.95	
80	0.9	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	
90	0.6	0.6	0.5	0.5	0.45	0.4	0.4			

AN INSTRUMENT FOR ASCERTAINING THE MELTING POINT OF BITUMINOUS MATERIALS.

Instruments in Use.—After an extended series of investigations it was found that the Kraemer and Sarnow method described in Chem. Ind., 1903, 26, (3), 55-57, is by far the most reliable one for determining the melting points of bitumens and pitches. This method consists briefly in inserting a 5-mm. plug of the plastic material in the lower end of an open glass tube of 6 to 7 mm. internal diameter, then introducing 5 grams of mercury, and suspending the tube in a beaker of water beside a thermometer. The liquid is heated with a small flame until the mercury drops through the plug of pitch. The temperature at which this occurs

is designated the softening or melting point of the substance examined.

The thickness of the plug does not, within reasonable limits, affect the result, so long as a tube of uniform bore (6 to 7 mm.) and the same quantity of mercury (5 grams) are employed. I have found, however, that the readings are influenced greatly by the

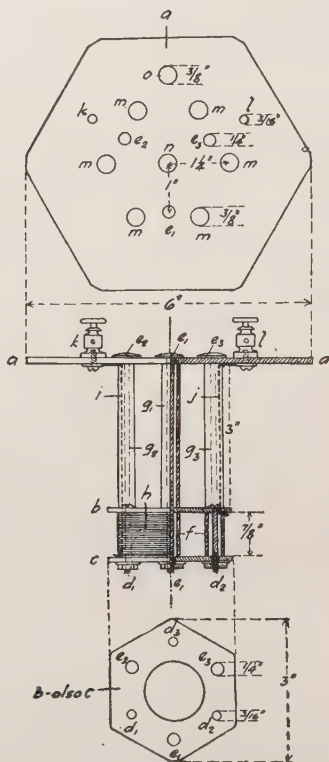


FIG. 4.

rate of heating. The more rapidly the bath is heated, the higher will the melting point appear. It is, moreover, impossible to control the rise in temperature with any degree of accuracy if the heating is performed with a naked flame.

Wendriner recognized this fact (Zeit. Angew. Chem., 1905, 18, 622-5), and suggested modifying the method by placing the tube

containing the pitch and mercury in an air bath consisting of a wide test tube, which in turn is immersed in a vessel of water. The latter is maintained at a constant temperature of 10° C. above the melting point throughout the determination. This, of course, must be determined by a preliminary test. Wendriner finds that it invariably takes from 8 to 10 minutes for the mercury to drop through the plug of bitumen, after the tube is placed in the heating bath.

This procedure is cumbersome, and even though it does give better results than the Kraemer and Sarnow method, yet it fails to control the rate of heating as well as may be desired.

Improved Method.—An electrical method was therefore devised which was aimed to overcome these difficulties. The heating is effected by means of a coil of resistance wire immersed in the bath of liquid containing the pitch tubes. The coil is connected with a rheostat which serves to control the heat to a nicety. Fig. 4 shows the details of the heating coil. Three slabs of slate *a*, *b* and *c* are fastened together by three small bronze bolts *d* and three large ones *e*. These are each enclosed in glass tubes, *f* and *g*, to prevent short circuiting. The coil *h* consists of 10 yds. of double cotton-covered No. 30 German-silver resistance wire wound in a single layer around the tubes and connected with two No. 20 German-silver leads *i* and *j* enclosed in the glass tubes *g*₂ and *g*₃ respectively. The leads terminate in two binding posts *k* and *l*. The coil after being assembled is treated with a high-grade insulating varnish and baked until hard.

Thirteen holes are drilled in a slate plate *a*; three *e* for the large bolts, six *m* for the melting point tubes, one *n* for the thermometer, two *k* and *i* for the binding posts, and one *o* for a glass tube which introduces a current of air to keep the liquid agitated.

The coil as described offers a resistance of 75 ohms, and allows the passage of approximately 1.5 amperes at a potential of 110 volts. This will serve to raise the temperature of 500 to 600 c.c. of water to the boiling point in a very few minutes, if the full current be applied. In running determinations, a metronome with a bell attachment is used, and the temperature is controlled by the rheostat, so as to increase *exactly four degrees Fahrenheit per minute*; or, in other words, one degree every 15 seconds. This rate is arbitrarily selected as being the most convenient.

Fig. 5 shows the general lay-out of the apparatus when assembled. It consists of a heating coil *a* immersed in a vessel *b* containing from 500 to 600 c.c. of water and in which the pitch tubes *c* and the thermometer *d* are suspended. The thermometer rests in a glass tube of the same general dimensions as the pitch tubes, but with its lower end sealed and containing sufficient mercury to cover the bulb. The heating coil is connected with the field rheostat *e* and a switch *f*. An eight-candle-power incandescent lamp *g* equipped with a reflector serves to illuminate

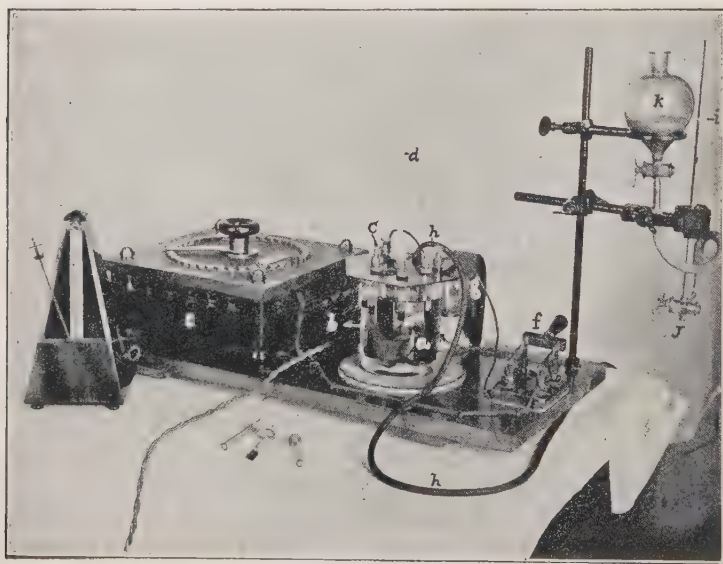


FIG. 5.

the pitch tubes. A current of air conducted through a flexible rubber tube *h* is introduced into the bath to effect a uniform distribution of heat.

The mercury is conveniently measured from a heavy-walled capillary tube *i* of 1 mm. bore, terminating in a three-way cock *j*. This is connected with a movable mercury reservoir *k*. The capillary tube is graduated to hold exactly 5 grams of mercury, and the measuring is performed automatically by so adjusting the level of the reservoir that the mercury will rise in the capillary tube to the exact height of the graduation.

Six tests may be run simultaneously, and duplicate determinations generally check to within a degree Fahrenheit.

There is absolutely no danger of the coil burning out, if it is kept immersed while being heated, on account of its peculiar skeleton-like construction, which permits the heat being dissipated as rapidly as it is generated. It has been found advantageous to etch marks 5 mm. from the lower ends of the melting point tubes, to serve as guides in filling. The tubes should be suspended in the beaker so that the liquid level is a short distance above these marks. The initial temperature of the water should always be at least 10° lower than the melting point of the material examined.

For substances melting above the boiling temperature of water, paraffine oil may be employed, as recommended by E. Graefe (*Chem. Ztg.*, 1906, 30, 298-9).

This electrical method greatly eliminates the "personal" equation which so largely enters as a disturbing element in the previous methods for determining the melting point of plastic substances.

BITUMINOUS MATERIALS FOR USE IN AND ON ROAD SURFACES AND MEANS OF DETERMINING THEIR CHARACTER.

BY CLIFFORD RICHARDSON.

The increased use of bituminous materials as palliatives for dust and for binding the mineral aggregate of road surfaces together, to enable them to resist modern traffic, has brought upon the market an extremely large number of these substances which are of very different character and of very different value. In view of this, it is important that the highway engineer should be able to distinguish the characteristics which differentiate them, which impart to some desirable qualities which are wholly or in part absent from others, and which make them suitable for different purposes. In considering the subject, it will first be essential to outline what these characteristics are, and then to show how they can be determined by the chemist in the laboratory and how the laboratory results can be interpreted by the engineer.

In a general way, it may be said that the nearer a bituminous cementing material approaches the type which is used in the construction of the highest grade of asphalt pavements, and at the same time can be satisfactorily introduced into the surface of the road under ordinary conditions, the more satisfactory it will be. As a matter of fact, roads which have been constructed with a paving cement, heating the mineral aggregate to permit of coating the particles of stone uniformly with the bitumen, have proved to be the most successful and resistant of any form that has been devised. The expense of such a method of procedure is, however, considered at the present time to be prohibitive, although it may eventually be found to be in reality the least so. In view of this fact, we must approach as nearly as possible to an asphalt paving cement such as is used in street pavements in cities, but which can be used in a heated form with stone or sand at atmospheric temperatures and without an elaborate plant. Service tests and experience can alone show, however, how far it will prove a

matter of economy to proceed in this direction, since the nearer the approach the more expensive will the material become.

Materials for this purpose must, therefore, be looked on as consisting of a cementing material or base, of the character of that which is used in street paving, combined with such an amount of a medium or diluent as to make their use possible under the conditions where they are to be employed.

Among the essential characteristics of a bituminous material for use in road construction, whether it be for a dust palliative or as a cementing material for a macadam surface, may first be cited stability; that is to say, it, or the base which it contains, must preserve and retain its original consistency and cementing properties for a long time without being converted by age and weathering into a brittle and inferior material.

A second essential is that it should have the necessary adhesive, binding and cementing properties, and not be short, cheesy, and oily.

Another desirable characteristic is that it shall not be too susceptible to changes of atmospheric temperature; that is to say, shall not harden at low temperatures nor become too liquid at higher temperatures.

It is equally important that it should not contain too large a proportion of light oils or medium which will volatilize readily at the temperature at which it is used, as this will result in undesirable changes in its consistency during its application.

A further characteristic is that the material shall have a proper body or viscosity, or shall contain a base or residual, after the removal of the lighter constituents by heat or evaporation, having these properties.

Finally, it is a requisite that these materials shall obtain, on the application of a moderate degree of heat, a comparatively low viscosity, so that they will be mobile, mix readily with cold stone, and under certain conditions possess the necessary penetrating or coating capacity.

Stability is probably the most important characteristic, since without it materials which were originally desirable may lose most of their valuable properties by hardening with age or in their application. As an example of such a substance, coal tar may be cited. When carefully prepared and of the proper con-

sistency, it possesses body and adhesiveness. It melts to a very mobile liquid at comparatively low temperatures, and has an excellent penetrating power. It has no stability, however, and hardens rapidly after a few years' ageing and exposure, becoming brittle and losing all its cementing power. This has been well shown by the experience gained during a period of more than thirty years in attempts to construct street pavements of the monolithic type with various mineral aggregates, using coal tar as a cementing material, with the result that the larger part of them have begun to disintegrate after some years, owing to hardening of the tar. Native solid bitumens, on the other hand, are, when carefully fluxed with suitable heavy oils, the most stable bituminous substances known.

Both coal tar, as originally used, and asphaltic compounds have most desirable adhesive properties. Paraffine hydrocarbons in themselves, and the heavier hydrocarbon oils of both the paraffine and asphaltic series, which have been treated with air at high temperatures—the so-called blown compounds—are very deficient in cementing properties, the latter being very granular, short and cheesy, while the former remain oily for an indefinite period and do not cement an aggregate together satisfactorily.

A lack of susceptibility to changes in atmospheric temperature is a characteristic worthy of consideration in a road cement or the base which it contains, where it is to be exposed, as is frequently the case, to extremes of from 20° or lower to 140° F. in the sun, and its behavior in this respect is important and should be determined. Neither the material itself, nor the more or less solid base which remains after the evaporation or distillation of a more or less liquid one, should show the great change in consistency which is found in some industrial by-products or residuals, making it a brittle one of little cementing value at low, and soft at high, temperatures.

The necessity for the other characteristics which have been mentioned is self-evident.

The object of this paper is to show how these properties may be rapidly identified in the laboratory by means of a chemical and physical examination, so that some information may be offered as to a bituminous cement before it is used, although naturally the final decision as to its value can only be arrived at

by experience in its use and manipulation, and by service tests for a number of years on roads subject to various traffic and under various conditions of environment.

The data which can be accumulated in the laboratory for the characterization of a bituminous cementing material for road construction consist of determinations of:

1. The specific gravity at 77° F. and the weight in pounds per gallon.
2. The amount of residual coke or fixed carbon which it yields on ignition.
3. The viscosity at temperatures which it will meet in the road surface, and will have in the course of application.
4. The flash point.
5. The adhesiveness.
6. The amount of oil volatilized at high temperatures, and the character of the residue or base remaining.
7. The adhesiveness of the lighter hydrocarbons in the medium and base.
8. The character of the hydrocarbons as revealed by the amount of paraffine scale which they contain.

The interpretation and value of the data can best be understood from a consideration of a series of analyses of such materials which have been made in the writer's laboratory in the past year, representing all classes, from a thin oil used in emulsion for laying dust, to a soft asphalt cement used as a binder for bituminous macadam or as a base for a thinner road compound. (See Table I.)

From the data given, it appears that various road oils and bituminous materials have a density of from 0.881 for an oil used in making emulsions for sprinkling purposes, to 1.214 for a coal-gas tar, or, expressing it otherwise, have different weights per gallon. This means that a ton of one material would have a larger volume than one of another, and, in so far as this is the case, would go further upon any surface, although the thinner oils would probably be absorbed much more rapidly than the thicker, which decidedly modifies this fact.

In a general way, among oils of the same class, a high specific gravity denotes a greater body and stability, but, of course, coal tar and asphaltic products cannot be compared.

The temperature at which the material flashes is indicative

TABLE I.

Test No.	Character.	Source.	Sp. Gr. at 77° F.	Wt. per Gal., lbs.	Flash Point, degrees F.	Residual Coke from Pure Bitumen, per cent.	Paraffine Scale, per cent.	Viscosity.				Film on glass after 48 hours.		First Drop of Distillate, degrees F.	Distillate below 700° F., per cent.	Residue—N.Y.T.T. Float at 150° F.
								N.Y.T.T. Float at 90° F.	N.Y.T.T. Float at 150° F.	Engler—100 cc. at 130° F.	Engler—100 cc. at 250° F.	Original.	Naphtha Extract.			
ASPHALT ROAD CEMENTS.																
.....	Genasco No. 482	B. A. P. Co. . . .	1.098	9.2	190	10.9	0.2	2' 9"	1'36"	*	5.0	Sticky	Sticky	308	24	4'10"
.....	" " 549	" " " " " "	1.016	8.5	440	9.6	0.0	11'54"	1'30"	*	24.7	"	"	650	Tr.	"
.....	" " 548	" " " " " "	0.990	8.2	440	6.2	0.0	69'55"	2'18"	*	22.2	"	"	650	"	"
.....	" " 547	" " " " " "	0.978	8.2	440	5.1	0.0	10'54"	1'30"	*		"	"	650	"	"
BLOWN OILS.																
110188	"H" grade	T. Co.	0.997	8.3	450+	10.7	0.4	*	17'38"	*	*	Sticky	Only	.....	0	.....
109745	" " " "	" " " " " "	0.99	8.3	450+	9.3	0.1	*	22'16"	*	6.1	"	"	.....	0	.....
109603	No. 14	S. A. R. Co. . .	0.976	8.1	450+	10.7	0.9	*	20"	*	*	"	"	.....	0	.....
109602	No. 877	A. A. & R. Co. .	0.973	8.1	450+	9.6	6.8	*	*	*	*	"	"	.....	0	.....
109746	Macadam binder.	T. Co.	0.971	8.1	450+	6.1	0.1	*	25"	*	*	"	"	.....	0	.....
RESIDUALS.																
97113	Cal. "G" grade	B. A. P. Co. . .	1.013	8.4	340	9.3	0.0	3'40"	***	11.1	11.1	Sticky	Only	380	7	1'2"
105214	Ky. road oil.	I. R. Co. . . .	0.974	8.1	485	7.4	2.0	2'21"	***	6.1	6.1	Only	"	636	0.5	.....
.....	Extra heavy flux	Sun Co. . . .	0.972	8.1	440	2.8	0.3	51"	***	4.0	4.0	Sticky	"	.....	0	.....
108512	Road binder No. 4	H. G. R. Co. . .	0.958	8.0	540	7.5	0.2	6'56"	***	22.7	22.7	"	"	700	0	1'3"
106125	Road bed oil	S. O. Co. . . .	0.944	7.9	265	7.1	2.0	1'24"	***	6.4	6.4	Slightly	"	418	8	.....
CRUDE OILS.																
108206	California	Sunset. . . .	0.968	8.1	195	3.6	0.0	9"	***	*	2.3	Sticky	Only	460	21	30"
105216	Kentucky	I. R. Co. . . .	0.981	7.8	390	3.3	2.1	28"	***	24.90	2.3	Only	"	658	0.5	.....
108234	Road bed oil	S. O. Co. . . .	0.910	7.6	285	1.0	1.6	***	***	2.57	1.1	"	"	496	42	.....
101645	Texas	G. R. Co. . . .	0.881	1.3	205	0.5	0.5	***	***	4.89	1.5	"	"	308	30	.....
TARS.																
101431	Tarvia	B. M. Co. . . .	1.214	10.1	220	14.4	0.0	1'30"	***	*	2.7	Sticky	Only	318	27	.....
105174	Crude g. h. tar	Providence	1.196	10.0	235	14.6	0.0	30"	***	23.85	4.2	"	"	280	20	.....
107653	Refined w. g. tar.	B. A. P. Co. . .	1.145	9.5	240	14.0	0.0	20"	***	25.96	2.2	"	"	450	34	.....

* Too viscous for determination.

** Too thin.

of the treatment to which it has been subjected. A low flash denotes a crude oil, while the higher the flash the more completely the lighter products have been removed by distillation.

The amount of residual coke or fixed carbon which a material yields, whether it is merely an oil or one with an added asphaltic base, is an important indication of the amount of base or binding material which it contains. The amount in such compounds varies from 0.2 per cent. in a crude Texas oil to nearly 12 per cent. in very dense asphaltic cements. It may be accepted that in the oils or materials of the same origin, the higher the percentage of residual coke the more desirable the material is, but those of different origin cannot be compared.

Coal tar products yield a high fixed carbon and, on this account and because of their adhesiveness, would be very satisfactory materials to use, were it not for the fact that they are unstable, either on heating or with age, and cannot be relied upon after a few years.

The amount of paraffine scale in any material, or in its base, is evidence that it or one of its constituents has been derived from a paraffine petroleum. If any considerable amount of scale is present it casts a serious cloud on the probable value of the material, as paraffine hydrocarbons are found to have little or no cementing value except when used as a flux in combination with some native solid bitumen.

The data given under the heading "Float at 90° F." are most important indications as to the consistency of any material. By means of this small apparatus, which has been described in the *Engineering Record* for May 1, 1909, page 584, it is possible to determine the relative consistency of various materials at temperatures to which they would ordinarily be exposed in the road surface, and at which they are applied to such surfaces. Of course the greater the number of minutes and seconds necessary for the plug to sink, the greater the viscosity and density of the material. This does not in all cases, however, have any relation to the specific gravity. As a rule, it may be said that a satisfactory material for cementing the mineral aggregate of a macadam surface should support the float for at least 3 minutes, and preferably for a longer time, as evidence of greater viscosity. As has been said, the more viscous a material as found in the road

surface, the more satisfactory it will be as a cementing material, having regard to its possible mobility at higher temperatures as it is introduced into the road surface. It is quite possible that one such as the Genasco Asphalt Cement No. 548, cited in the table, which has a float test of 69 minutes 55 seconds, would be too nearly an approach to a sheet asphalt paving cement to be used with entire satisfaction in cold weather, but could it be introduced—and this will depend on atmospheric temperature—it would be preferable to any of the lighter materials. The float test is one of the most satisfactory means known of specifying the consistency of the denser materials.

A comparison of the viscosity of the various materials at various temperatures can also be determined with an Engler viscosimeter, in which a definite volume of oil is allowed to run through a definite sized aperture and the length of time required compared with that for the same volume of water. The results are stated with reference to water as unity. This determination is of value in showing how mobile the materials will become when heated for application to the mineral aggregate. It is, of course, much the same for the lighter oils as for water, but with the heaviest ones which are used for cementing the mineral aggregate of the wearing surface, it is much greater. Of course, the compound which has the greater mobility at 250° F. and the greater viscosity at 90° F. should be considered the better material, since it will have a greater penetrating power when applied, and a greater viscosity on the roadway at the temperatures to which it is exposed. The determination is, therefore, of great practical value.

Another means of judging a bituminous material is dependent on the fact that the naphtha-soluble bitumen in those which are most adhesive and satisfactory, is very adhesive when the naphtha solution is evaporated on a glass plate and exposed to the air for some time. If a residue of this kind remains oily under such circumstances, the material will not prove satisfactory so far as adhesiveness is concerned.

On distilling 100 grams of a bituminous material in a 6-oz. glass retort, the temperature being raised at the rate of 10° F. a minute to 700° F. with the bulb of the thermometer completely immersed in the oil, it is of interest to note the point at which the first drop of distillate comes off, as evidence of the character of the

lighter oils in the compound. The amount and character of the residue which remains is also determined. The denser materials naturally will have a larger percentage of residue, and the most desirable ones show but little or no distillate under these conditions. Valuable inferences may be drawn from the data obtained in this way, as well as from the examination of the consistency of the residue which is left in the retort. Of course, in the case of coal tars or road compounds in which a tar is the medium, the amount of distillate above 700 °F. is very much augmented over that in the petroleum and asphaltic materials.

The distillation of the material in a retort at a temperature of 700° F. has been found more advantageous than subjecting a smaller amount of the material to a lower temperature for an extended period of time, not only on account of the greater celerity of the test, but because the non-volatile residue is not altered to the same extent by this quick treatment as happens when a smaller amount is exposed for the longer period to lower temperatures.

Taking into consideration all the data that may be obtained in the manner described, it is possible to-day to form a better opinion in regard to the characteristics of bituminous materials for road construction than we have been able to do in the past.

In general, it may be said that those materials which contain the largest amount of solid native bitumens compatible with their use with cold aggregates, are much more desirable than any others as far as the construction of macadam highways is concerned, for the reason that surfaces constructed with them bear a much closer relation to sheet asphalt pavements in their capacity to resist the conditions to which they are exposed than materials originating in petroleum oils alone, even if the latter are of an asphaltic nature.

Methods for determining the characteristics which have been described will be presented in another paper accompanying this.* It is not claimed, of course, that those which are proposed may not be modified, extended, or improved upon in the future, but, as they are based upon an experience of more than twenty years in an examination of bituminous substances, they present the best practice which has been arrived at during that period.

* "Methods for the Examination of Bituminous Materials for Road Construction," by Richardson and Forrest, p. 588.—Ed.

METHODS FOR THE EXAMINATION OF BITUMINOUS MATERIALS FOR ROAD CONSTRUCTION.*

BY CLIFFORD RICHARDSON AND C. N. FORREST.

So much attention has been directed of late to the problem of bituminous highway construction, and so many inquiries have been made in regard to methods for the examination of bituminous materials in use for this purpose, that it seems that it may be of interest and value to present the methods in use in the New York Testing Laboratory, which have been based on an experience of twenty-two years in the study of various bitumens.

Specific Gravity.—The specific gravity of light oils is determined with a pycnometer or a Westphal balance at 25° C. Heavy substances, too viscous for testing by the above instruments, are examined by the Kirschbraun method, as follows:

Take a test tube about $\frac{1}{2}$ in. in diameter and cut it off to give a $1\frac{3}{4}$ - by $\frac{1}{2}$ -in. tube. Flare it out to carry a fine wire. Put about 10 grams of the oil or asphalt into it, and suspend it in an oven to remove air bubbles and drive off the water. Cool and weigh accurately in air and immerse in distilled water at 25° C. to a fixed mark on the wire and weigh. Previous to filling the tube with the sample, determine its weight carefully in air and in water at 25° C., immersed to the fixed mark. These weighings give the weights of the tube alone in air and in water, and the combined weights of the tube and the sample in air and water. The specific gravity is calculated in this way:

$$\text{Sp. gr.} = \frac{\text{Wt. of sample in air}}{\text{Loss of wt. in water}}$$

Or, using the following notation:

Weight of tube in air	a
Weight of tube and sample in air	b
Weight of tube in water	c
Weight of tube and sample in water	d

$$\text{Sp. gr.} = \frac{b-a}{(b-a)-(d-c)} \dots\dots\dots (1)$$

* Practiced in the New York Testing Laboratory.

When the specific gravity of the sample is less than unity, the second expression in the denominator ($d-c$) is a negative quantity and is added to the original weight of the sample ($b-a$), inasmuch as the buoyancy of the sample will overcome its own weight, and, to a certain extent, will also reduce the weight of the tube in water, making c greater than d .

The formula in this case may be also expressed

$$\text{Sp. gr.} = \frac{b-a}{(b-a) + (c-d)} \dots \dots \dots (2)$$

When the specific gravity of the sample is greater than unity, d will be greater than c and the first formula applies, without confusion. As an example, take a blown oil, the specific gravity of which was determined in our laboratory according to this method:

Weight of tube in air	a =	4.7870
Weight of tube and sample in air	b =	16.7900
Weight of tube in water, 25° C.	c =	2.8565
Weight of tube and sample in water	d =	2.6425

by formula (2)

$$\text{Sp. gr.} = \frac{16.7900 - 4.7870}{(16.7900 - 4.7870) + (2.8565 - 2.6425)} = \frac{12.0030}{12.2170} = 0.9817$$

This may seem a bit complicated at first, but it will be noticed that the factors a and c are constants, which can be used for the same tube without change, and the calculation becomes very simple after a few trials.

The advantages of the method are in doing away with the inconveniences of handling a large amount of oil, and the ease with which air bubbles can be removed. Of course, it can be used only with oils which are viscous enough to be retained in the tube when under water.

Flash Test.—The flash point is determined in a New York State closed oil tester. The water bath is, of course, removed and the oil heated directly with a flame of a size to raise the temperature at the rate of 20° F. per minute, while a small flame from a capillary glass or metal tube is used for flashing. The flame should be applied at 5° intervals. The determination should be repeated for oils that flash at unexpected temperatures. The water must be removed from the oil or flux before putting it in the tester.

Bitumen Soluble in Carbon Disulphide, or Total Bitumen.—

One gram of the dry material is weighed out and introduced into a 200-c.c. Erlenmeyer flask of Jena glass, and covered with about 100 c.c. of carbon disulphide. It is then set aside for at least 5 hours, or over night, at the temperature of the laboratory. In the meantime, a Gooch crucible is prepared with an asbestos felt and weighed. This Gooch crucible is of special form, with a large filtering surface. It holds 30 c.c., is 4.4 cms. wide at the top tapering to 3.6 cms. at the bottom, and 2.6 cms. deep. This is much better for percolation work than the usual narrow form of Gooch. The felt is made by beating up long-fiber Italian asbestos in a mortar, and suspending the finer particles in water and quickly pouring off from the coarse particles. Too much of the latter should not be removed, or the felt will be too dense. The decanted asbestos and water are shaken up and what is found to be a proper amount poured into the crucible, which has, in the meantime, been attached to a vacuum filtering-flask by the proper glass and rubber connections. As soon as the asbestos has somewhat settled, the vacuum pump is started and the felt firmly drawn on the bottom of the crucible. It is then dried, ignited, and weighed.

After standing a proper time, the disulphide is decanted very carefully upon the filter, which is supported in the neck of a wide-mouthed flask and allowed to run through without suction. The flask, after being tipped to pour the first portion, is not again placed erect, in order to avoid stirring up any insoluble material, but is held at an angle on any suitable base, such as a clay chimney. After all the disulphide has been decanted, more is added and the insoluble matter shaken up with it. This is allowed to settle, and decanted as before, the insoluble matter being finally brought on the filter and washed with the solvent until clean. The excess of disulphide is allowed to evaporate from the Gooch crucible at the temperature of the room. It is then dried for a short time at 100° C. and weighed. The loss of weight is the percentage of bitumen soluble in carbon disulphide.

In the meantime the filtrate, transferred to a platinum dish, is placed in a good draught and lighted. When all the disulphide has burned, the bitumen remaining in the dish is burned off over a lamp and the mineral residue, which escaped the filter, is weighed. The weight is added to that of the Gooch crucible or subtracted

from the percentage of bitumen found without its consideration, as a correction. Care must be used in this method of procedure that the solvent does not creep over the sides of the crucible and that the outside is free from bitumen before weighing. In order to avoid this, the crucible is preferably supported in the neck of a flask with three constrictions, the neck extending above the top of the crucible and the latter being covered with a watch-glass.

Bitumen Soluble in Naphtha.—One gram of the substance is weighed into a 200-c.c. Erlenmeyer flask, covered with naphtha, and allowed to stand, as in estimating total bitumen; in fact, the entire process is the same, with the exception that one or two precautions must be observed. It is well not to attempt to break up any lumps with a stirring rod, as the substance, especially the softer asphalts, may then adhere to the rod or flask and be difficult to detach. It may also be necessary to treat the substance with several portions of the solvent. No heat is applied at any time in the process, and the filtration is made without suction.

Character of Bitumen Soluble in Naphtha.—The filtrate containing the naphtha-soluble bitumen is evaporated spontaneously in a crystallizing dish until the naphtha is expelled. At 77° F., the residue in the dish is tested with the fingers to ascertain whether it is merely oily or of a sticky and adhesive character.

Residual Coke or Fixed Carbon.—This determination should be made according to the method described for coal in the *Journal of the American Chemical Society*, 1899, Vol. 21, page 1116.

Place 1 gram of pure bitumen in a platinum crucible weighing 20 or 30 grams and having a tightly fitting cover. Heat over the full flame of a Bunsen burner for 7 minutes. The crucible should be supported on a platinum triangle with the bottom 6 to 8 cms. above the top of the burner. The flame should be fully 20 cms. high when burning free, and the determination should be made in a place free from draughts. The upper surface of the cover should burn clear, but the under surface should remain covered with carbon.

The residue minus the small impurity of ash in the pure bitumen is the fixed carbon, which should be calculated to 100 per cent. with the volatile hydrocarbons, excluding the inorganic matter.

Paraffine Scale.—The distillation method is employed for this purpose.

One hundred grams of the oil are distilled rapidly in a 6-oz. retort to dry coke. Five grams of the well mixed distillate are treated in a 2-oz. flask with 25 c.c. of Squibb's ether; after mixing together thoroughly, 25 c.c. of Squibb's absolute alcohol are added, and the flask packed closely in a freezing mixture of finely crushed ice and salt for at least 30 minutes. Filter off the precipitate quickly by means of a suction pump, using a No. 575 C. S. & S. 9-cm. hardened filter, cooled by the above freezing mixture in a suitable apparatus.

Rinse and wash the precipitate with a 1 to 1 Squibb's alcohol and ether mixture, cooled to 0° F., until free from oil, 50 c.c. of the wash solution being usually sufficient. When sucked dry, remove the paper, and transfer the waxy precipitate to a small glass crystallizing dish. Dry on a steam bath and determine the weight of paraffine scale remaining in the dish.

$$\frac{\text{Wt. of Paraffine}}{\text{Distillate taken}} \times \text{Percentage of Original Distillate} = \\ \text{Percentage of Paraffine Scale.}$$

Viscosity.—The viscosity of bituminous road materials is determined in the Engler viscosimeter at any temperature desired. The full quantity, 250 c.c., is placed in the apparatus and raised to the temperature at which it is desired to make the test; 100 c.c. are then permitted to flow into a graduated flask of the above capacity, and the time of flow in seconds noted. The result may be expressed either in seconds or by ratio compared with the time of flow of an equal quantity of water at 77° F.

Road binders should be too viscous for testing in the Engler apparatus at temperatures below 250° to 350° F., and to determine the consistency of such materials at normal or slightly elevated temperatures, the New York Testing Laboratory float apparatus is employed.*

The apparatus consists of two parts, an aluminum float or saucer and a conical brass collar. The two parts are made separately for reasons of economy, so that one or two of the floats will be sufficient for an indefinite number of brass collars.

In using the apparatus, the brass collar is placed upon a brass plate the surface of which has been amalgamated, and

* See *Eng. Rec.*, Vol. 59, p. 584, May 1, 1909.

filled with the bitumen under examination, after it has been softened sufficiently to flow freely by gentle beating. The collar must be level-full, and as soon as the bitumen has cooled sufficiently to handle it is placed in ice water at 41° F. for 15 minutes. It is then attached to a float and immediately placed upon the surface of the water, which is maintained at 90° F. or any other temperature desired.

As the plug of bitumen in the brass collar becomes warm and fluid, it is gradually forced out of the collar, and as soon as the water gains entrance to the saucer the entire apparatus sinks below the surface. The number of seconds elapsing between the time of placing the apparatus on the water and the time of sinking, is determined most conveniently by means of a stop watch, and is considered as the consistency of the bitumen under examination.

Cementing Value.—Petroleum oils have very feeble if any cementing value. Materials requiring a high temperature to flow freely will not adhere to cold road metal. To determine these properties, the material under examination is heated to the temperature at which it is used in practical work, and a portion is then allowed to flow over the surface of a slab of marble or glass, 4 ins. wide, 5 ins. long, and 1 in. thick. After standing 24 hours at 77° F., the film upon the slab must be decidedly sticky when tested with the fingers, and must adhere so that it cannot be pulled off.

Volatile Substances.—One hundred grams of the material are placed in a 6-oz. tubulated glass retort, with the bulb of an accurate thermometer immersed in the same. Heat is now applied so that the temperature rises at the rate of 10° per minute to 700° F. The distillate, if any, is regarded as the amount of volatile substance in the material. The residue is examined by the New York Testing Laboratory float for consistency, and compared with the results obtained upon the original material by this test.

A MACHINE FOR TESTING THE DUCTILITY OF BITUMINOUS PAVING CEMENTS.

BY FRANCIS P. SMITH.

Description.—The machine herein described was designed and is being used by the writer for the testing of bituminous materials possessing a ductility up to 90 cms. For materials of low ductility, a horizontal pull and an open tank are permissible and possibly more convenient. Such devices are not suitable, however, for the examination of very ductile materials, since portions of the test briquette are liable to sag and rest on the bottom of the tank before it is ruptured, making the pull uneven and the measurement of the distance inaccurate. By pulling the briquette vertically this objection is overcome, the results obtained are accurate, and the machine is equally well adapted for the examination of all classes of bituminous paving materials.

This machine is shown in Fig. 1. The vertical brass screw *c* is slotted so that it may be raised and lowered without being revolved. This screw passes through a threaded hole in the center of the large gear wheel *d*, and is raised or lowered as this gear wheel is revolved by means of the hand wheel *e* and the intermediate gears *f*, *g* and *h*. The proportions of these various gears and the pitch of the thread on the brass screw are so arranged that by revolving the hand gear 16 times per minute, the two ends of the briquette will be pulled apart at the rate of 5 cms. per minute. In order to time the revolution of the hand wheel correctly, it is provided with three pins set at equal distances apart on its periphery. These pins are so arranged as to engage with a reed at one point of their revolution, thus producing an audible click without offering any appreciable resistance to the revolution of the wheel. By keeping these clicks synchronized with a metronome set to 48 beats per minute, it is possible to regulate with extreme accuracy the speed of the wheel and at the same time closely observe the behavior of the sample being tested. Any desired mechanical means may be, of course, substituted for the hand wheel. The screw is made of brass to prevent it from rusting, as it is continually immersed in water.

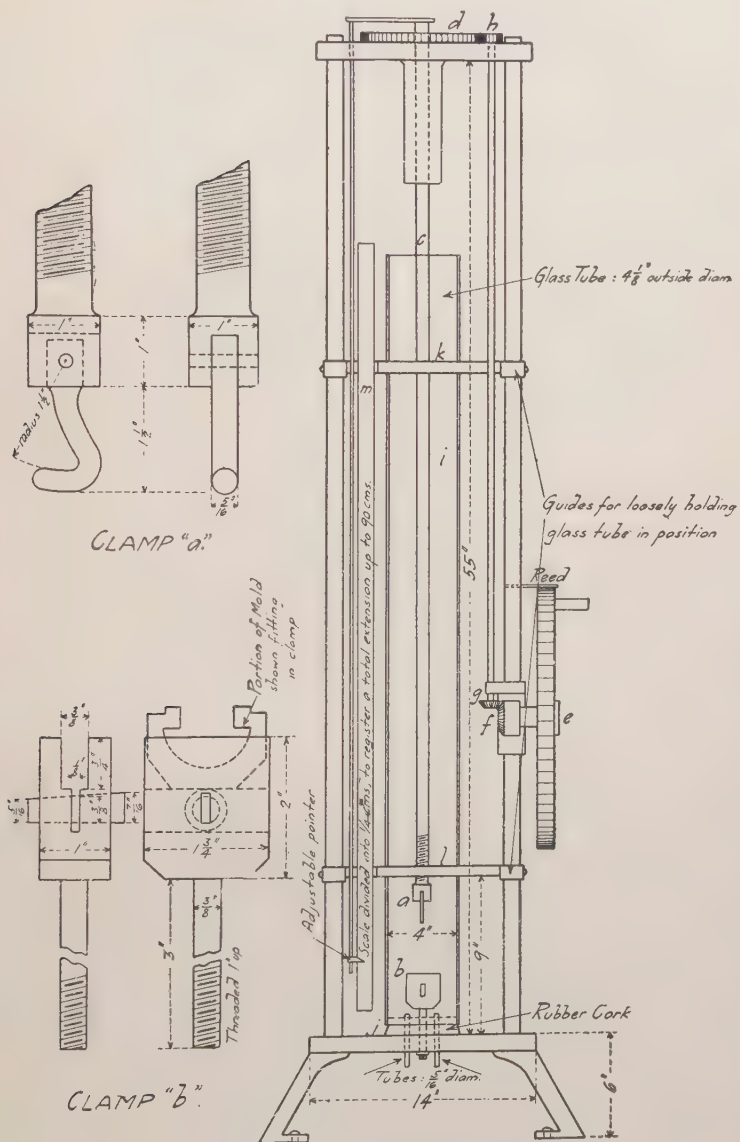


FIG. 1.—Ductility Machine.

The glass tube *i* is 4 ins. inside diameter and 43 ins. long and is held loosely in guides *k* and *l*. Its lower end is closed with a large rubber stopper *j*, through which passes two filling and emptying tubes and the bolt attached to the briquette clamp *b*. The upper and lower ends are protected from breaking by means of brass collars cemented on to the tube. A scale *m* divided into fourths of a centimeter is attached to the guides which support the glass tube. A long rod attached to the pulling screw *c* is provided with an adjustable pointer which passes over this scale. At the commencement of the operation this pointer is set at the zero mark and it is read at the moment the thread of bitumen breaks, thus giving the extension in centimeters of the sample under examination. Four upright columns screwed into a base and top make the framework of the machine.

Method of Operation.—The briquette of bituminous material is inserted in the clamps *a* and *b* by raising the glass tube and supporting it on the lower guide. The portion of the mold adhering to one end of the briquette is inserted in clamp *b*, and fastened there by passing the key through the clamp and the brass ring in the end of the mold. The brass screw is then lowered until the hook on its lower end engages with the ring on the other half of the mold attached to the upper end of the briquette. The glass tube is then lowered and placed tightly on the rubber stopper *j*, after which the tube is filled with water at the desired temperature. A thermometer suspended at a convenient point in the water will register any variation in temperature which may take place during the test. The pointer is then set at zero and the hand wheel put in motion. The distance registered by the pointer at the moment the thread of bitumen breaks, gives the ductility expressed in centimeters of the sample under examination. The tube may then be emptied of water through the drainage tubes passing through the stopper, after which it is raised as before and the old briquette removed, when the machine is ready for another test.

The clamps in this machine are especially made to fit the Dow form of briquette shown in Fig. 2. After numerous trials this form of briquette was adopted as being the most suitable. Briquettes of other forms, including those shaped like a rod, were discarded owing to the lack of homogeneity in some bitumens

which rendered their pull irregular unless the briquette was so shaped that it would fail at some one definite point of least cross section.

The dimensions of this briquette are as follows: 1 cm. in thickness throughout; distance between clips, 3 cms.; width at mouth of clips, 2 cms.; width at minimum cross section half way between clips, 1 cm.

The molding of the briquette may be done as follows: The mold should be placed upon a brass plate. To prevent the asphalt from adhering to the plate and the inner side of the two removable pieces of the mold, *a* and *a'*, they should be well amalgamated. The different pieces of the mold should be held together in a clamp or by means of an India rubber band.

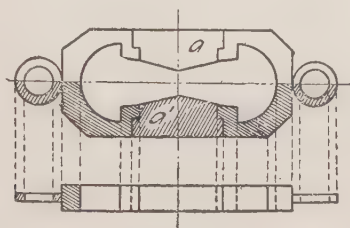


FIG. 2.

The material to be tested is poured into the mold while in a molten state, a slight excess being added to allow for shrinkage on cooling. After the cement is nearly cooled, the briquette is smoothed off level by means of a heated palette knife. When cooled, the clamp is taken off and the two side pieces *a* and *a'* removed, leaving the briquette of asphalt firmly attached to the two ends of the mold, which thus serve as clips. The briquette should then be immersed in water maintained at 77° F. for at least 30 minutes, or until the whole mass of bitumen is at that temperature. It is then pulled apart as described above.

During the operation of pulling, the temperature of the water should not vary more than $\frac{1}{2}^{\circ}$ from the standard temperature. While this test is usually conducted at 77° F., it may also be made at 32° F. When made at this latter temperature, extreme care must be taken not to fracture the briquette, as materials of this kind are frequently very brittle at low temperatures. For

this reason it is customary to pull the briquettes apart at a rate of $\frac{1}{4}$ cm. per minute when testing them at 32° F., instead of 5 cms. per minute as employed when testing them at 77° F.

When testing asphalts, asphalt cements, or bitumens for ductility, it is customary to first bring them to a consistency of 50 penetration at 77° F. (Dow Machine), in order that the results obtained may be comparative. This is done by softening them with a flux similar to that which it is proposed to use in practice. The ductility test is then made on the mixture of asphalt and flux so prepared.

Different asphalts vary considerably in purity and character of bitumen. Any appreciable amount of mineral matter or inert bitumen will largely affect the ductility, and for this reason the test should be made on materials of approximately the same purity as well as consistency. Asphalts to be examined for ductility are therefore usually divided into three classes and are given a preliminary treatment as described below, depending upon their classification.

1. Asphalts containing over 96 per cent. of bitumen soluble in carbon disulphide and free from lumps of inert bitumen.
2. Asphalts containing less than 96 per cent. of bitumen soluble in carbon disulphide, in which the bitumen is homogeneous, or nearly so; i. e., contains no lumps of inert bitumen.
3. Asphalts in which the bitumen is not homogeneous; i. e., containing lumps of hard bitumen which, although soluble in carbon disulphide, are insoluble in the softer bitumen, even in a molten condition, which forms part of the bitumen under examination.

Asphalts coming under the first classification need no preliminary treatment other than softening as previously described until they have a consistency of 50 penetration at 77° F.

Asphalts coming under the second classification should be subjected to the following treatment:

Sufficient quantity of the refined hard asphalt, before having been fluxed to yield 150 grams of pure bitumen, is treated with carbon disulphide in an Erlenmeyer flask. After standing for

2 or 3 hours, the flask is shaken until none of the asphalt is seen adhering to the sides or bottom of the flask, after which it is set aside and allowed to stand 24 hours. The solvent is then carefully decanted from the residue into a second flask. The residue is again treated with the solvent, shaken, allowed to subside, and decanted as before. This is continued until the solvent is practically colorless or of a light straw color. The combined solutions, after standing at least 24 hours after the last addition of solution, should then be carefully decanted off and the solvent distilled until only sufficient remains to keep the extracted bitumen liquid. The residue is then poured into a large evaporating dish and as much of the remaining solvent as possible evaporated off on a steam bath. To facilitate the removal of the last particles of carbon disulphide from the bitumen while on the steam bath, it should be stirred from time to time. After this treatment on the steam bath, $\frac{1}{2}$ to 1 c.c. of water should be incorporated into the bitumen and the heating continued over a burner until all foaming ceases, after which the dish containing the bitumen should be placed in a hot air oven and kept at 300° F. for 30 minutes. While heating the extracted bitumen over the burner, it should be stirred constantly with a thermometer, and care exercised that the temperature never exceeds 300° F. The extracted bitumen is brought to a consistency of 50 penetration at 77° F. by the addition of sufficient flux, and is then ready for testing.

Asphalts coming under the third classification should be treated as follows:

The asphalt, asphalt cement, or bitumen is heated in an air bath at a temperature between 300° and 350° F., together with a 20-mesh sieve and a 50-mesh sieve. When the material is in a thoroughly molten condition, it is first strained through the heated 20-mesh sieve and afterwards through the heated 50-mesh sieve. The molten cement must not be forced through the sieves, but must run through by gravity alone.

If the material thus obtained contains less than 96 per cent. of bitumen soluble in carbon disulphide, it must be still further purified by the method described for asphalts coming under the second classification; otherwise it may be softened with flux to the proper consistency and is then ready for testing.

A FURTHER DEVELOPMENT OF THE PENETROMETER
AS USED IN THE DETERMINATION OF
THE CONSISTENCY OF SEMI-SOLID
BITUMENS.

BY C. N. FORREST.

In conjunction with Mr. Clifford Richardson, the author presented a paper at the meeting of this Society in 1907, Proceedings of the Tenth Annual Meeting, Vol. VII, pp. 626-631,

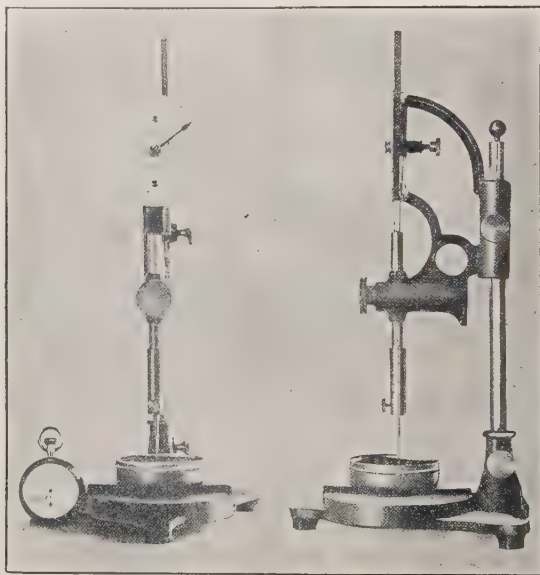


FIG. 1.

upon the subject of "The Development of the Penetrometer as Used in the Determination of the Consistency of Semi-Solid Bitumens."

The instrument exhibited at that time was intended for laboratory use, although it was strongly constructed to withstand

a reasonable amount of abuse. It has, in the interim, fully met the expectations of the designers, but there has arisen a considerable demand for a portable penetrometer which may be carried about conveniently by an inspector, and set up and used at paving plants and elsewhere. Such an instrument is shown in Fig. 1.

The diameter of the dial is 3 ins., and the height over all is but 11 ins. The weight upon the needle point is fixed at 100 grams. The hand indicating the degree of penetration is adjustable, and the time of penetration should be taken by a watch.

To adjust and maintain the standard temperature of 77° F. at which the test is made, the instrument and the sample of bitumen, the latter in a tin box $\frac{1}{2}$ in. deep by $2\frac{1}{2}$ ins. diameter, are placed in a tub of water, thus obviating the necessity of adjusting the temperature of the room. A depth of $2\frac{1}{2}$ ins. of water is sufficient.

For convenience of transportation, the miniature penetrometer is taken apart and packed into a neat oak carrying-case, 11 by $6\frac{1}{2}$ by 4 ins.

A NEW METHOD AND APPARATUS FOR THE DETERMINATION OF THE SPECIFIC GRAVITY OF SEMI-SOLID SUBSTANCES.

BY ALBERT SOMMER.

I beg to introduce herewith an apparatus for the determination of the specific gravity of asphalts, waxes, and all kinds of semi-solid or solid adhesive and flexible materials.

The exact industrial determination of specific gravity of semi-liquid bodies has always been connected with more or less difficulty, if it was not, as in some cases, even impossible. The present method of determining the specific gravity of asphalts in petroleum refineries, for instance, consists of using an hydrometer on the melted asphalt and then figuring back to the volume at 60° F. This, of course, is not accurate, due to the more or less unknown expansion or contraction during the chilling. To weigh an asphalt which is solid under ordinary temperatures in water or solutions is also connected with great difficulty, inasmuch as it is very difficult to free the sample sufficiently from air bubbles to obtain its correct specific gravity. It may be well nigh true to state that although the use of bituminous materials of the consistency of asphalt is daily becoming larger and more general, there is no method for taking this very important characteristic in a quick, simple, and reliable way.

The method I propose seems to be the solution of this problem, inasmuch as it permits the determination of the specific gravity of an asphalt in its ordinary consistency without the use of a balance, and in the easiest, quickest way. The main feature of the method is to let the asphalt chill in a small cylindrical vessel which is divided into two parts, the lower holding exactly 10 c. c., and the upper being removable from the cup by the connecting thread (see Fig. 1). The principle of the instrument is to have the shrinkage take place in the upper removable sleeve, so that after the removal of the same the lower cup contains a certain fixed volume.

The entire vessel is filled with melted asphalt and heated for a little while at a temperature slightly above the melting point, in order to thoroughly remove air bubbles or traces of water. After the surface is clear, the vessel is allowed to cool, at first in air (to avoid sudden contraction and hence separation of the asphalt from the sides of the tube), and then in water of the desired temperature, which will usually be 60° F. The sample should be left in the water a sufficient time to thoroughly adopt its temperature, and a half hour will not be too long for this purpose. Then it is removed from the water, wiped dry, and

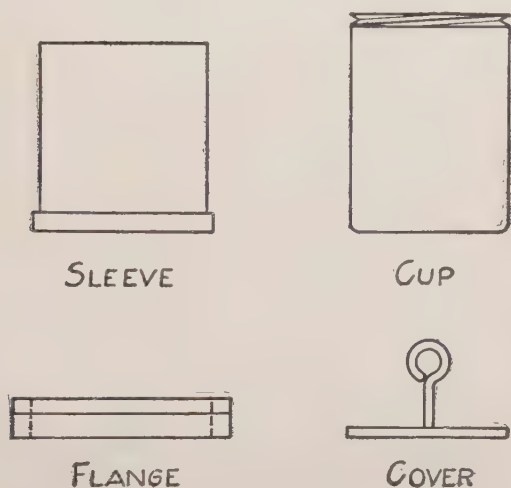


FIG. 1.

the upper extension part or "sleeve" is removed. If the asphalt is so hard that it renders the unscrewing difficult, the upper part should be warmed with a Bunsen burner. The sleeve is then pulled off and the asphalt which extends above the level of the cup is cut off with a broad knife.

The cup will then contain exactly 10 c. c. of asphalt at 60° F. This quantity can be directly weighed on an analytical balance, and the specific gravity ascertained by dividing the number of grams of asphalt by ten. The following method, however, simplifies the procedure:

After the cup is filled flush, a cover is slid on it from the side, and fastened to it by a flange (see Fig. 1). The cup and its

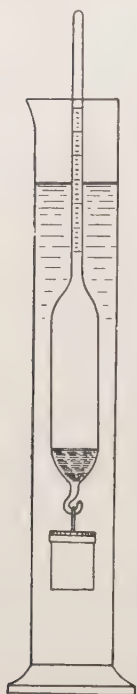


FIG. 2.

contents are then suspended from a special hydrometer and the whole instrument is placed in a jar containing water at 60° F., as shown in Fig. 2. If any air bubbles form on the instrument, it should be twisted once or twice quickly and they will escape. The specific gravity can then be read directly on the stem of the hydrometer without correction. The method is accurate to the third decimal place, and the slight mistake which could be caused by irregularity in the cutting is so trifling that it would not affect the third decimal place when only 10 c. c. are used.

The cup is very simple and easy to clean; care should be taken, however, that only mineral solvents are applied, in order not to interfere with its weight.

The method can be applied for asphalt, road oils, tars, waxes, etc. It is, however, also perfectly reliable for any oils and other semi-liquids, such as molasses, etc.

For various products, instruments should be ordered with the stem graduated in accordance with the average specific gravity of the product. The instrument which is put on the market now has a range from 0.950 to 1.100, which is that of most asphalts and asphaltic materials. Any other range, of course, can be substituted.

GENERAL DISCUSSION ON BITUMINOUS MATERIALS.

MR. ALBERT SOMMER.—The paper presented by Mr. Richardson undoubtedly contains a number of very interesting and important points, but I do not feel that we are in a position to-day to devise a multitude of chemical and physical tests without being certain as to their importance and relevancy. Very little actual experience in building bituminous macadam roads has been acquired and there is no doubt but that the problem is different from that of sheet asphalt and other work. Many instances can be cited where specifications have been devised without actual knowledge as to their value in practical work, and consequently numerous tests are mentioned which are of no importance. Mr. Sommer.

Mr. Richardson describes the problem of building macadam roads as analogous with the construction of sheet asphalt pavement, but I cannot agree with him on that point. In constructing sheet asphalt pavements the hot bituminous material is mixed with hot stone and, as Mr. Richardson observes, there is no indication at present that this method will be adopted for the building of macadam roads in the near future. There is no question that the ideal asphalt for roads should have about the same consistency as asphalt cement used for sheet paving. At the same time, hot stone not being available for macadam work, the bitumen must be introduced in a softer form. Now, when making a sheet asphalt surface, we would of necessity choose such asphalt which, having the proper consistency from the start, will not change afterwards. Hence, if such asphalt has to be made by fluxing, the flux applied should be of a permanent character, and this is the feature of the residual products which are rightly in use for that purpose. In road making, however, we *want* the original consistency to change, down to the point where the base of about 60 penetration is reached; and hence, in my opinion, residual products with their saturated heavy oils and tarry character, are entirely out of place for such kind of work. In road building

Mr. Sommer. we face the necessity of applying a material in a consistency which is too liquid to be a strong, satisfactory binder, and which should, in spite of this, form such a binder not only in a comparatively short time, but also be as permanent as possible after it has once reached its final consistency.

I believe that everyone of us knows that residual products, especially those of paraffine basis, have given a great deal of trouble on account of not "setting up" properly, and remaining in their original liquid condition, forming pools and making the road perhaps worse than it would have been without any binder.

Under these circumstances I cannot quite see how it can be demanded that the asphaltic material put on the macadam road should, under all circumstances, retain its consistency. As stated, this is all right for sheet asphalt paving, but I would say that in the road we should have a material which sets up rapidly to a favorable degree of hardness, and then no more.

Of course, this cannot be attained when residual products are used for fluxing. Such products contain a great many saturated, unchangeable, or paraffine oils of lubricating character. I should, therefore, suggest that the following tests which specify a residual character should be revised or abandoned, inasmuch as they offer no advantage whatsoever to the road engineer, but, in my opinion, even necessitate furnishing an inferior product:

1. High flash.
2. Small amount of evaporation at 300° and 400° F.
3. Great viscosity at 100° F.

Such specifications force the manufacturers of compounds for road building to apply residual fluxes of lubricating character, instead of others which could be used to better advantage. It would undoubtedly be better for the engineer if such oils (which increase the viscosity without at the same time increasing the asphaltic contents) should be totally eliminated.

I should also say that I cannot see any value in the test for residual coke or fixed carbons; and until somebody can elucidate that question and say what amount would be injurious and what not, or what influence a certain amount of fixed carbon has on the total compound, such tests should be abandoned. To a road engineer who contemplates employing bituminous binder for

his work, I should say that only the following properties be considered: Mr. Sommer.

- (a) It shall contain as much *asphalt* of suitable consistency for building the road as possible.
- (b) It shall be as *fluid* as possible in order to permit its proper application by the method proposed.
- (c) For this reason all such products must be eliminated *a priori*, which would increase the viscosity without increasing the percentage of asphalt.
- (d) If one purchases asphaltic compounds, he does not want to buy anything which is not bituminous, and therefore the solubility test should protect him against all impurities.

The most desirable way of building a macadam road, to my mind, is to mix crusher-run stone, dry and dustless but with the screenings, with bitumen, and to spread this mixture on the road. That cold stone will be applied in most cases seems to be a foregone conclusion. For this reason a solid asphalt will in most cases be out of the question. No matter, however, what mixing method should be finally decided upon, a satisfactory asphaltic material must, at any rate, comply with the above requirements.

As to tests which are in accordance with the above deductions, the following methods should be applied:

SEMI-LIQUID COMPOUNDS.

1. *Viscosity*.—To be taken at 100° C. on the Engler instrument.
2. *Asphaltic Contents*.—To be determined by heating 50 grams of the product to a temperature not exceeding 500° F. in an oven, until a certain percentage is evaporated. If, for instance, a product of 80 per cent. asphaltic content was specified, 20 per cent. should be evaporated, and the penetration of the residue should then be not less than 100 when tested at 77° F. on the Dow machine, using a 100-gram weight.

Mr. Sommer.

3. *Distillation*.—A certain percentage of the compound should be subjected to Engler distillation, and the viscosity of the distillate noted when 10, 20, or 30 per cent. of the distillate shall have gone over.
4. *Solubility*.—The amount of insoluble matter should be ascertained by hot, continuous extraction of the material with carbon bisulphide and carbon tetrachloride, using one of the standard methods. The extraction methods now proposed are inaccurate and will furnish varying results under varying conditions.
5. *Destructive Distillation*.—Bitumen should be subjected to destructive distillation; all the paraffine scale will then be contained in the distillate as scale, and should be determined by either the Holde or Zaloziecki method.

I also beg to submit a specification proposed for a macadam binder of 80 per cent. asphaltic contents, as follows:

1. It shall be soluble in bisulphide of carbon to not less than 99.5 per cent.
2. It shall be soluble in carbon tetrachloride to not less than 99.5 per cent. (Solubility in tetrachloride indicates absence of so-called "carbenes," which are always an indication of the asphalt having been overheated.)
3. When heated to a temperature not exceeding 500° F., until 20 per cent. is evaporated, the residue shall have a penetration of not more than 10 mm. when tested at 77° F. on the Dow machine, using a No. 2 needle weighted with 100 grams.
4. The compound shall be sufficiently liquid at working temperatures, that when tested in an Engler viscosimeter at 212° F., not more than 200 seconds shall be required for 50 c. c. to flow out.
5. The solid contents of this material shall consist only of asphalt, and the consistency of the residue shall not be due to any other solid substance, such as paraffine. The paraffine scale of the total compound shall not exceed 1 per cent., and shall be determined by destructive distillation of the entire compound to

coke. The determination of the paraffine scale in the distillate shall be made by the Holde method. Mr. Sommer.

6. The asphaltic binder shall not contain any dirt or water, but consist of pure bitumen only. Tar or substances recovered from acid sludge shall not be admitted.

As regards the list which Mr. Richardson gives in his paper on tests of various road compounds, I should say that his classification is not quite correct. All the Genasco products are called "Asphalt Road Cements," and everything else is classified under the following: "Blown Oils, Residual Oils, Crude Oils, and Tars." Closer investigation would show that this classification is not justified. Besides, there is a certain test offered which I may say is not quite impersonal enough. A film on glass is prepared from the original compound and from its naphtha extract, and it is determined whether that film after 48 hours is "sticky" or "oily." I note that only Genasco products, as well as their naphtha extract, are "sticky," and that the naphtha extracts of the others are "oily."

I would like to say in this connection that I cannot see how the exact difference between "stickiness" and "oiliness" can be determined. What has the stickiness of the naphtha extract to do with the original compound? Why is it that the Genasco naphtha extracts should be "sticky," when we all know that they are also fluxed with some residual oils, and that such residual oils would go in the naphtha extract just the same as the oils contained in the other compounds? I may say that such classification and unwarranted treatment of one kind of product should be avoided, or at least guarded against in broad publicity.

I suggest these requirements and reasons for changes in the specifications with the hope that they will form a basis for the advancement which is necessary along these lines if we are to bring the road building industry to such a position that it will adequately meet the needs of the public. At the same time, I feel sure that the suggested tests indicate only such properties as undoubtedly have a bearing on the qualities necessary for road making, and I do not think that this attitude will be disputed.

MR. JAMES W. HOWARD.—I should like to call attention to a Mr. Howard.
seeming inconsistency between what Mr. Richardson advocates in his present paper on Bituminous Materials regarding the

Mr. Howard. kind of asphalt suitable for use, and what he advocates in another paper, now in print and intended to be read at a Road Congress in Seattle, July 4-8. In the present paper he states practically as follows:

"In general, it may be said that those materials which contain the largest amount of solid native bitumens . . . are much more desirable than others, . . . for the reason that road surfaces constructed with them bear a much closer relation to sheet asphalt pavements . . . than materials originating in petroleum oils alone, even if the latter are of an asphaltic nature."

Whereas in the other paper referred to he states practically as follows:

"On the Pacific slope the opportunity for the construction of roadways of the highest type is facilitated by the fact that vast quantities of residual pitch and flux, most of it of suitable quality, are available as a cementing material or binder, so that all that is necessary is a certain amount of skill and experience to attain the best results."

By residual pitch, as is well known, he thus names refined asphalts made from California and other petroleum oils of an asphaltic nature. Thus, it seems to me, he advocates one kind of material, solid native bitumen, on the Atlantic coast as the best, and another kind, bitumen from asphaltic oils, on the Pacific coast.

Mr. Boorman. MR. T. HUGH BOORMAN.—Most of those present who have studied practical street and road building will agree with Mr. Richardson that the mineral aggregate in asphalt macadam should be heated, and that a plant is necessary to obtain any really satisfactory result of the thorough mixing of mineral aggregate with the bituminous binder necessary for a permanent surface to a macadam road. Mr. Richardson certainly voices the sentiments of many when he states that the expense of such procedure, at present considered prohibitive, may be found to be the least so.

A question I should like to ask is: What is Mr. Richardson's definition of "native solid bitumens," which he states are, when carefully fluxed with suitable heavy oil, the most staple bituminous substances known; does "native" mean oil asphalts solely, excluding such asphalt as Bermudez? Perhaps this is Mr. Richardson's idea, as I notice in his Seattle address on "Asphalt Macadam

Roadways," published prior to this meeting, that he refers to **Mr. Boorman.** California oil asphalt as a suitable cementing material.

It is rather disheartening to be informed that the value of a bituminous cement can only be arrived at "by service tests for a number of years." As a practical worker for nearly thirty-seven years in asphalt construction for streets and roads and for asphalt concrete work as laid for engine foundations, I have no hesitation in stating that with the use of such quality of asphalt as has been hitherto satisfactorily used for the standard sheet asphalt pavements, and with the mineral aggregate heated and properly mixed, an entirely satisfactory surface can be applied to old or new macadam roads.

MR. JAMES OWEN.—I came here to acquire whatever information possible on this subject of road construction. I am not a chemist. All the chemistry I ever knew has been volatilized like some of our binders; but I have built a great many roads and am building them now. I am very desirous that we should be guided in our road practice in the near future by some positively established facts. To that end I would suggest that the Society should collect data, not only on successes, but on failures. I imagine that the asphalt people acquired all their early information from failures rather than successes and I think the road of the future will grow out of such failures into final perfection. I wish to urge the necessity of positive data indicating whether tar, bitumen, asphaltic oil, or asphalt is best. **Mr. Owen.**

It was stated in one of the papers to-day that tar is a volatile product. Forty years ago when we had the tar fever I laid a great many tar pavements. As a matter of curiosity I visited some of them a year ago. I found them just as good as they were when put down. There are asphaltic oil pavements which are successful. We want to find out where they are and what they are made of. We all know that the Warren pavement was made of tar, and that it has been in many cases very successful, while in other cases it proved a failure. In my own city it has been a positive failure. It seems to me, therefore, that Committee H of this Society should ask the cooperation of the road engineers of this country to obtain detailed information during the next two or three years as to what they have done and what they are doing. There are probably twenty or thirty chemists and four or five hundred road engineers.

Mr. Owen. The road engineers can contribute their practical experience each in his limited field, and the chemists should take the data and formulate the results. We want to ascertain the lowest cost at which a good serviceable road can be constructed.

Mr. Hubbard. MR. P. HUBBARD.—I wish to say that I thoroughly agree with Mr. Owen in regard to reporting unsuccessful as well as successful experiments. There has been too great a tendency so far for engineers to write up reports of their successes only. We can learn just as much and sometimes more from failures than from successes.

Mr. Abraham. MR. HERBERT ABRAHAM.—There is just one matter of which I wish to speak. In Mr. Richardson's paper on Bituminous Materials a method is given for determining the bitumen by means of carbon disulphide. Mr. Sommer a few minutes ago said that he preferred the hot extraction process.

I have found very good results from using the Buechner filtering funnel, 3 ins. in diameter, with hardened paper. Another advantage of this procedure is that the paper may be burned off and the ash in the insoluble organic matter determined directly, without using the method of difference.

Mr. Sommer. MR. SOMMER.—In the asphalts on which I work principally, the amount of insoluble matter is so small that it is almost absorbed by a Gooch crucible and asbestos filter. Furthermore, I have found that the difference between cold extraction and hot extraction is very small; also, that cold extraction is much more subject to the individual equation than the hot process, which is more automatic and independent of personality. I prefer such tests as can be made with the influence of personality eliminated. In the extraction method which I proposed a while ago, the temperature in the extraction thimble is always constant because the substance is exposed to both vapors and the liquid running back from the condenser. For these reasons I would decidedly prefer an automatic extraction method at boiling temperature.

Mr. Howard. MR. HOWARD.—May I ask Mr. Sommer if he will kindly state what he regards as the working boiling temperature of carbon disulphide?

Mr. Sommer. MR. SOMMER.—I think 46° C. For this reason, and because it is not so much above the room temperature, why not adopt the automatic method if it is available?

MR. ABRAHAM.—I have tried this method of hot extraction myself, and found that it takes quite a long while. In certain cases, particularly if there is a large percentage of insoluble matter present, it is apt to clog up the pores of the paper so that sometimes it does not work at all. With the cold method by the use of the Buechner funnel, I think the longest it ever takes to filter is about 5 minutes, and often as low as 30 seconds. In practical tests where time counts I think this ought to be a deciding factor in selecting a test. Mr. Abraham.

MR. SOMMER.—I should like to say one more word in regard to naphtha extraction. Naphthas varying in specific gravity from 0.88 to as low as 0.62 have been proposed. I have found that gasolines obtained from different crude oils have different solvent power on asphalt, even if they have the same specific gravity. This is due to the different percentages of cyclic hydrocarbons which they contain. Therefore specific gravity alone is by no means sufficient to specify the naphtha for the examination of asphalt. I am now making experiments with pentane in this connection, but they are not as yet concluded and I am therefore not ready to report on the same. Pentane is a chemical substance which can now be obtained practically everywhere, inasmuch as it is being used in the gas industry for candle power standard. Mr. Sommer.

NOTES ON TESTING TURBINE OIL.

BY ROBERT JOB.

The lubrication of heavy rapidly-moving machinery used largely in power plants is of extreme importance, owing to the value of the engines and to the necessity of continuous running. In many places the heating of a bearing may result in cutting off power, with the attendant inconvenience and loss. At times, as for instance in some types of turbines, the bearings are very closely adjusted and if the oil is not entirely clear and free from waxy substances, clogging and heating very quickly result. In many places also oil is used in a "system," i. e., in a large tank which frequently holds thousands of gallons. The oil is pumped above the bearings and allowed to flood them, and thus is used over and over again. In course of time it has been found that with some oils a settling of a waxy sludge results, causing clogging of the filters and other difficulties.

In view of these conditions, it was thought desirable to determine whether some simple test could be developed to be used in connection with routine examinations of shipments, in order to bar this undesirable quality. As an aid in studying the subject, a number of red engine and turbine oils, some of which had given good service and others bad service, were thoroughly tested and it was found that the usual constants gave no indication of the service obtained in this particular. Clearness and freedom from all turbidity were of importance, but mere color or lack of color seemed to have little influence, and good service results were obtained with oils which were of a red color, as well as with those which were filtered to an amber color.

After experimenting with a number of tests, it was found that on heating the oils to a temperature of 450° F., all of the oils which had given bad service showed a very marked darkening of color, while those which had proved satisfactory showed very little change. Our investigations indicated that filtering to a light color, as for instance that of a "sun-bleached" oil, is unnecessary, since good results have been obtained with oil of fairly deep

color even under exacting conditions ; but the point of importance appeared to be that the oil had been filtered or else chemically treated in such a manner that the waxy substances, the so-called "amorphous waxes," had been completely removed, and on applying the heating test only a slight darkening of color resulted. It seems therefore to be of decided advantage to specify, in addition to other requirements, that an oil for the above purposes on being heated to a temperature of 450° F., and held there for 5 minutes, shall show not more than a slight darkening of color. The test, of course, is that commonly used in testing 300° oil for burning purposes.

It is known that the elimination of the waxes causes a decided increase in the ease with which the oil separates from hot water when thoroughly shaken with it, and this condition can be taken advantage of by prescribing that when 1 oz. of the oil is placed in a 4-oz. sample bottle with 2 oz. of boiling water, the bottle corked and shaken hard for one minute and let stand, the oil shall separate from the water within a specified time, depending upon the nature of the oil, and that there shall be no appearance of waxy substances at the line of demarcation of the oil and water.

These tests are simple and practical, and seem to give an excellent index, in conjunction with the usual tests, of the value of oils used under these conditions of service.

DISCUSSION.

The President.

THE PRESIDENT.—I would like to ask Mr. Job whether it is possible that some of this waxy material that gives difficulty after the oil has been in service had formed during the use of it? We experimented several years ago with some of the petroleumums by filling a burette and turning it bottom side up into a tin cup containing some of the same oil; then connecting the delivery end of the burette, which was now uppermost, with a source of oxygen gas, drawing the oil down 50 or more c.c., and allowing the material to stand for a while. We found that under these conditions, even at ordinary temperatures, quite a number of the petroleumums absorbed oxygen, and the oil would gradually rise up in the burette as the oxygen was absorbed, giving apparently oxidized hydrocarbons of some kind. That might be a part of this waxy material.

Mr. Job.

MR. ROBERT JOB.—I think it is a fact that these waxes form as a result of service. It was only a few months ago that we made an exposure test of a very similar oil. The statement had been made that it is impossible for this particular oil to be acted on by oxygen, and to determine the matter we took the sample and exposed it in a large clock glass to the sun and air. After about 2 months it was found that the proportion of free acids had increased twenty-fold; also that the oil had become decidedly turbid, evidently due to the formation of waxy compounds of some kind, oxidation products, I presume. So it is perfectly possible that a great deal of this change may have been due to exposure to the air and the gradual formation of compounds. In the particular oils that gave this formation, we found upon applying the heating test that practically no change of color resulted, and later that we got good service from the oil. When bad service was obtained, irrespective of the color at the start, we found that this darkening of color resulted. We tested altogether, I suppose, 12 or 15 different kinds of oil from different manufacturers, in order to have a fair check upon the method, and in all we examined the same condition was found to exist.

MR. P. H. CONRADSON.—I should like to ask Mr. Job whether he examined the oil prior to its use and whether he found much difference between the new oil and the oil that had been used for some time. Mr. Conradson.

MR. JOB.—We found that the oils in service gradually became more or less turbid and rancid, depending upon the conditions. Mr. Job.

MR. CONRADSON.—Was the amount of acidity of the oil that had been in service for some time determined in comparison with that of the new oil? Mr. Conradson.

MR. JOB.—Yes, it was. We found in one case that the acidity had increased about ten-fold; in the case of one oil that had been in service for approximately one year the acidity had increased about five-fold. Mr. Job.

MR. CONRADSON.—I asked this question as a matter of general interest. I have done a great deal of investigation work in the same line during the past year; and there might be some points that will interest the Society. I have taken an oil that had never been in service and its acidity as expressed in percentage was say 0.25 or 0.3 per cent; whereas the same oil which had been in service from 4 to 6 months in continuous circulation in the system, had increased in some cases to 1.5 and 2 per cent. acidity or over, showing that there was evidently a change going on. A few weeks ago I had occasion to go to Cleveland and talk over some matters with Mr. Mayberry, one of the greatest petroleum experts in the country. I told him that the practice was to have ten barrels of oil in the oil system. The oil passing through the journal and bearing in an extremely thin film repeatedly comes in contact with air and perhaps also moisture, at a temperature which is naturally rather high, and a decided change takes place sooner or later, depending upon the amount of oil in the system, the capacity of the turbines, and materially, of course, upon the quality of the oil. I asked him whether he thought it was due to certain oxygen compounds formed in oil that had been in service a long time? He said it was possible that small amounts of oxygen were absorbed and formed oxidation products; but he thought that the discoloration was due to the removal of the hydrogen from the hydrocarbons, forming polymerized hydrocarbon compounds. Mr. Conradson.

Mr. Conradson. We have had some very peculiar experiences in connection with turbine oils. At the present time one of the most difficult things we have to contend with is the formation of heavy tarry compounds, waxy compounds, perhaps, that clog up the filters. Mr. Mayberry explains this by the continual giving off of hydrogen from the oil so that it becomes heavier and heavier, and that this is not due so much to oxidation.

Some of the discoloration is of course due to the wearing of the bearing and journal. There can be no question about that; but the discoloration is also due to the oil itself. The question is, to get an oil that will give the least trouble considering the severe service conditions.

Mr. Job. **MR. JOB.**—With the oil exposed in the clock glass a decided discoloration resulted. It had not been in service but was standing in the window exposed to the sun and air. The color had darkened in a couple of months from a very light straw to quite a deep amber, simply through oxidation.

FUEL INVESTIGATIONS, GEOLOGICAL SURVEY.
PROGRESS DURING THE YEAR ENDING
JUNE 30, 1909.

By J. A. HOLMES.

The first item deserving mention in this report is the fact that the fuel-testing plant which was located in St. Louis from August, 1904, to March, 1907, and during the remainder of 1907 at Norfolk, Va., was in 1908 installed at Pittsburg, Pa., where adequate grounds and buildings were furnished for this purpose by the Government.

Among the reports published during the year embodying the results of work at the station, were the following bulletins:

- B 334. The Burning of Coal without Smoke in Boiler Plants, D. T. Randall.
- B 336. Washing and Coking of Coals and Cupola Coke Tests, Richard Moldenke and A. W. Belden.
- B 339. The Purchase of Coal under Government and Commercial Specifications, D. T. Randall.
- B 343. Binders for Briquettes, J. E. Mills.
- B 362. Mine Sampling and Chemical Analyses of Coal, J. S. Burrows.
- B 363. Tests of Coal and Briquettes on Locomotives, W. F. M. Goss.
- B 364. Tests of Coal and Briquettes as Fuel for House-Heating Boilers, D. T. Randall.
- B 367. The Significance of Drafts in Steam Boiler Practice, W. T. Ray and Henry Kreisinger.
- B 368. Washing and Coking Tests, A. W. Belden and John W. Groves.
- B 373. The Smokeless Combustion of Coal in Boiler Plants, D. T. Randall.

Among a considerable number of bulletins now in preparation are three volumes of from 300 to 500 pages each, embodying a resumé of these investigations from 1904 to 1907, inclusive: one embracing the chemical results; a second, the results of from 500 to 600 tests of fuel in boiler furnaces; and a third, the results of the gas-producer fuel investigations.

Among the special investigations conducted during the year and deserving of mention in this report, may be included

(c) house-heating experiments involving the use of bituminous coal in horizontal tubular boilers, with special investigations with reference to the heating of army posts, naval stations, other public buildings, etc., and (d) the use of producers in the utilization of low-grade fuels.

During the past year we were endeavoring to find low-grade fuels in the Pittsburg district for use in these producer investigations, and we were informed that no coal could be found in that region of sufficiently low grade to answer our needs. In the mining of the Pittsburg coal beds we found that from 5 to 7 ft. of the good coal were being taken out, and 1 to 3 ft. of low-grade material left as roof to avoid caving. This was described as being of such a low grade that it had no commercial value whatever in the Pittsburg district. It was necessary for us to have a quantity of this low-grade roof coal mined for our special use. We found it to contain only from 12 to 15 per cent. of ash, and it burned easily and efficiently both in the gas producer and in the boilers. In many portions of the United States this would be regarded as a high-grade coal, while in the Pittsburg district it is left in the mines, together with pillars of the best coal.

In connection with this last-mentioned investigation, a number of typical mines in different portions of the country have been examined with a view to determining the nature and extent of this low-grade fuel, and the extent to which coal was wasted in ordinary mining operations. These inquiries and examinations indicate that the loss of coal in mining in the United States will probably exceed 250,000,000 tons per annum.

One of the many investigations conducted during the year is that in connection with the combustion problems. A special combustion chamber 40 ft. long has been constructed, which at its rear end is connected with a 220-H. P. Heine boiler. This special combustion chamber is operated with a 150-H. P. Murphy stoker. The smoke seems to disappear and the combustion to be fairly complete long before the rear end of this furnace is reached by the gases in combustion, so that no smoke whatever is made in connection with the operation of the furnace, while the 150-H. P. stoker easily operates the 220-H. P. boiler.

Another line of chemical research has been under way with

a view of determining the nature of coal itself. Dr. J. C. W. Frazer has been investigating the solubility of the hydrocarbons in coal, and has succeeded in finding solvents to dissolve from 60 to 80 per cent. of them. He is now endeavoring to make the necessary chemical analyses to determine the composition of these materials in solution, and to find solvents for the remainder.

Dr. H. C. Porter has been conducting investigations into the products of distillation of coal at different fixed temperatures; the composition of the distillates given off at different temperatures; and the inequality of fuel value of the different grades of volatile matter. Mr. Stanton and Dr. Frazer have also been conducting a series of investigations into the composition of flue gases. It has been shown in this connection that the volatile matter which frequently escapes only partly consumed in the flue gases, is quite variable in its heat producing value, and that some of the unaccounted-for heat losses may in many cases be explained in this manner.

A study of the ash and clinker has been inaugurated by Mr. F. M. Stanton under the general supervision of Professor N. W. Lord, consulting chemist.

Another investigation, under the supervision of Professor A. H. White, relates to the coals suitable for illuminating gas manufacture.

Dr. Irving C. Allen has been engaged in a study of the petroleum for fuel and general power purposes.

Still another investigation relating to the behavior of different grades of kerosene on two types of oil engines, has been pursued under the direction of Mr. R. M. Strong.

The work of the general inspection of coals purchased by the Government and the purchase of these coals under specification, was given general consideration and precedence over other work in the direction of the plans of the station.

The general chemical investigations that have been conducted during the year include the approximate and ultimate chemical analyses and the calorimeter determinations of probably not less than 1,000 coals collected from different mines. These analyses are all made on samples which have been collected with great care as representing the coal supplies actually available in the specific mines. They have, therefore, an unusual value, in that the analyses represent a definite and specific deposit of coal.

As will be seen from the above outline, the main purposes of these investigations have been the prevention of waste in mining and the more efficient utilization of fuels in the varied industries of the country, especially in the use of fuels by the Government. We already recognize the fact that at present there is an enormous waste, both in the mining and in the use of valuable fuel. We all realize, further, that the price of coal in the United States at the mine is less than one-half the price of coal at the mines in various European countries. It is therefore impossible for the operators at the present prices of coal to go to the extra expense necessary for the complete recovery of the coal from the mines; and the very cheapness of the coal itself makes us careless concerning its more efficient use. Our coal supply, however, is not inexhaustible. On the contrary, at the present increasing rate of consumption the coal supply of the United States will be practically exhausted before the end of the next century.

Persons who may suppose that the "present increasing rate" in the consumption of coal in the United States cannot continue, should bear in mind the following facts:

1. The present rate of increase in coal production is a little less than, but nearly an average of, that which has maintained during the past three-quarters of a century.

2. The per capita consumption of coal in the United States was in 1880, 1.4 tons; in 1890, 2.3 tons; in 1900, 3.2 tons; and in 1907, 4.7 tons.

3. The above and abundant similar data indicate that the people of the United States who were during the past two centuries devoting themselves to the conquest of the country, and largely to agricultural pursuits, have only within the past few decades entered upon the mining and manufacturing industries, and that if our abundant natural resources are properly husbanded, this country should become more and more the great manufacturing country of the world.

4. The population of this country has increased from 5,308,000 in 1800, to 75,569,000 in 1900; and a careful study of the problem of increase in population in this and in other countries leads to the reasonable expectation that by 1950 the United States will have a population of 150,000,000, and that by the year 2000 its population will approach 250,000,000.

DISCUSSION.

MR. R. H. FERNALD. -In connection with the tests being Mr. Fernald. carried on at Pittsburg, it seems to me that the successful use of these low-grade fuels in the gas producer will naturally result in the concentration of power plants at the mines for utilizing this material.

A few months ago it was my pleasure to inspect similar propositions in Europe and I believe there are a few points in connection with this movement abroad that may interest this Society. In England I was able to learn of practically no installations utilizing low-grade fuels. One company operating a producer plant of 16,000 H. P. and using coal from their own mines, delivers the good grades of fuel to the plant and makes no use of the poorer grades. They are much interested in the low-grade fuel problem and realize that it is a most important one. They feel that the United States is moving in the right direction in the effort to systematically investigate the possibilities of using the so-called refuse material, and are following our efforts with the keenest interest.

The only country with which I am familiar that is using low-grade fuels to any extent is Germany, where I visited one or two such plants. The location of one of these I am not authorized to give, but at the time of my visit this plant had been installed about twelve months. This is a by-product recovery plant used for the production of sulphate of ammonia and producer gas. The fuel used consisted of a mixture of refuse from the culm pile, mine roofing slabs, and washery refuse, the resulting combination containing about 53 per cent. ash. It took about nine months to find out how to handle this fuel, but during the three months preceding my visit the plant is reported to have given satisfaction.

Another plant in southern Germany is using roofing slabs, which are reported to contain 60 per cent. ash. This material looks like big slabs of slate. At the time of my visit, which had not been previously announced, they were operating a 1,000-H. P.

Mr. Fernald. engine and one of 250 H. P., with gas from this fuel, and were installing an additional 500-H. P. unit. The gas was also being used under numerous steam boilers. From this central power plant they were furnishing light for the neighboring towns and power for the local street railway, as well as doing the mine hoisting. Both of the plants mentioned above are located at the mines so that transportation charges for the fuel are eliminated.

In this country we are endeavoring to demonstrate the wisdom of similar methods of power development and centralization. At the Pittsburg Testing Station we are using refuse material from the mines from which we develop producer gas. This gas is in turn utilized in a gas engine connected to an electric generator by means of which power is supplied to the various portions of the plant. It is possible to compress the gas and transmit it over considerable distance, but up to the present time, so far as I am informed, this basis of operation has not proved financially successful. One plant in England of several thousand H. P. is transmitting producer gas over an extended area. The company has a 3-ft. gas main of about 37 miles total length. There is no difficulty in generating gas of a constant quality and in fulfilling the guarantees, but the people along the line are afraid to take the gas for the simple reason that they are not accustomed to producer gas in their ordinary work. As a result the development of this process has been slow. The owners of the plant have been obliged to install all types of furnaces in order to demonstrate the possibility of using the gas for various applications aside from power purposes.

In Sweden there are many installations of producer-gas power plants all the way from 20 H. P. up to several hundred H. P. utilizing peat as fuel. I visited some of these last year and found them working very satisfactorily. Probably the first producer-gas power plant to be installed at the "mine" is located in Sweden. A plant of 300-H. P. capacity is located directly in the heart of a peat bog, so that the peat supplied to the producer is directly available without transportation. The high-voltage electric current is transmitted to the town, 3 miles away.

The utilization of these low-grade fuels right at the point of production is along the line upon which we are working at the

Testing Station. We not only have been able to use a great many **Mr. Fernald.** high-ash and poor-grade fuels, but we have demonstrated that it is quite possible to erect producer-gas power plants and generate electric current for commercial purposes when the only fuel used is of this low-grade type.

INFLUENCE OF THE VARIOUS CONSTITUENTS OF COAL ON THE EFFICIENCY AND CAPACITY OF BOILER FURNACES.*

BY D. T. RANDALL AND PERRY BARKER.

It is difficult to burn all coals with equal efficiency. This may be due to either the character or the size of the coal, or to both. Having made a large number of tests on different coals, one may by systematic study draw some general conclusions regarding the influence of moisture, volatile matter, and possibly, in extreme cases, the effect of the presence of ash in the coal. Unfortunately

TABLE I.—COMPARATIVE ANALYSES OF COALS MINED IN THE
SAME STATE.†

	Pocahontas, Tazewell Co., W. Va.	Clarksburg, Harrison Co., W. Va.	Ehrenfeld, Cambria Co., Pa.	Bruce, Allegheny Co., Pa.
Moisture.....	1.63%	2.01%	3.51%	2.61%
Volatile matter.....	17.17 "	37.31 "	16.82 "	34.92 "
Fixed carbon.....	75.34 "	52.13 "	73.04 "	56.30 "
Ash.....	5.86 "	8.55 "	6.63 "	6.17 "
	100.00 "	100.00 "	100.00 "	100.00 "
Sulphur	0.75%	2.54%	0.94%	1.26%
B. t. u. as received..	14,672	13,811	14,279	13,997

for the purpose of comparison, the coals high in moisture are usually high in volatile matter and ash as well. That there is a difference in the composition of coals will readily be seen from a comparison of coals mined in the same state, as shown in Table I. It will be seen from this table that the volatile matter is very much greater in coal mined in some localities than in others, and it may be expected that these coals will behave differently when burned under a boiler.

* Contributions from the Arthur D. Little, Inc., Laboratory of Engineering Chemistry.

† Results reported in Bulletins of the U. S. Geological Survey.

The Influence of Moisture.—It is of course understood that any moisture in a coal reduces the heating value accordingly. In addition to this influence, there is a further loss due to the absorption of heat in the furnace, which lowers the temperature of the gases, causing a larger percentage of loss in the gases escaping from the boiler. This influence is not readily seen when burning coals which have only a slight variation in the moisture content, but in cases where there is an excessive amount of moisture this influence may be readily traced, as for example in western lignites in which the moisture sometimes reaches 40 or 45 per cent. of the

TABLE II.—RESULTS OF EVAPORATIVE TESTS OF ILLINOIS WASHED COAL ON A CHAIN GRATE STOKER.*

	Test No. 47.	Test No. 131.
Size of coal.....	$\frac{1}{4}$ to $\frac{3}{4}$ in.	$\frac{3}{8}$ to $\frac{7}{8}$ in.
Moisture—Coal as fired.....	10.72%	19.83%
Ash—Coal as fired.....	7.31 "	7.68 "
Volatile matter—Coal free from ash and moisture.....	39.59 "	42.61 "
B. t. u. in coal as fired.....	11,898	10,274
Carbon dioxide.....	12.60%	11.46%
Carbon in ash.....	4.00 "	1.75 "
Equivalent evaporation from and at 212° F. per pound coal as fired.....	8.24 "	7.49 "
Efficiency of boiler and grate.....	66.89 "	70.39 "
Efficiency of boiler.....	69.93 "	71.76 "

weight of the fuel. On the other hand there are many people who believe that a certain percentage of moisture is favorable to good combustion and, as has been indicated above, the influence of moisture is so small that its effect cannot be separated from the many other influences which affect the results of a boiler test. It can be seen from Table II that even considerable percentages of moisture may not result in greater loss than might be due to some other influence, such as the size of the coal. It will be noted that even though the moisture content of one of the coals shown in this table exceeds that of the other coal by about 10 per cent., the results are better. This may probably be accounted for by a difference in the size of the coal.

* Illinois Engineering Experiment Station. L. P. Breckenridge, Director.

Influence of Volatile Matter.—With a poorly designed furnace the volatile matter in a coal is allowed to escape unburned even when the fuel is burned at moderate rates. With well designed furnaces a loss of combustible gases occurs when they are operated beyond a certain capacity, varying with the furnace and

TABLE III.—RELATION BETWEEN VOLATILE MATTER, EFFICIENCY, AND SMOKE: HOUSE-HEATING BOILERS.*

Number of Tests Averaged.	Volatile Matter. Coal free from Ash and Moisture, per cent.	Efficiency, per cent.	Black Smoke, per cent.
4	18.30	60.56	18.2
7	34.70	54.11	22.1
11	44.46	47.19	32.9

the kind of coal. Tables III and IV show in a general way what may be expected from the two extremes in furnace design—those which are adapted to burning high volatile coals, and those which are not. The house boiler on which the above tests were conducted may be considered as one of the lowest types of furnaces for burning coals high in volatile matter, for the reason that the

TABLE IV.—RELATION BETWEEN VOLATILE MATTER, EFFICIENCY, AND SMOKE: HAND-FIRED HEINE BOILER.*

Number of Tests Averaged.	Volatile Matter. Coal free from Ash and Moisture, per cent.	Efficiency, per cent.	Black Smoke, per cent.
8	17.47	67.16	3.1
19	34.48	67.24	12.9
37	44.13	65.25	18.0

rate of combustion is low and the firebox is made up of iron surfaces which have a cooling effect on the gases as soon as they escape from the coal. At the Government Fuel-Testing Plant, results as shown in Table IV were obtained on a hand-fired Heine boiler with a fire-brick combustion chamber.

* Data from Bulletins U. S. Geological Survey.

The Influence of Ash.—It is not possible to determine the effect of small variations in the percentage of ash on the results obtained. In this respect the character of the ash is of more importance than the quantity. Clinkers and ash reduce the efficiency and capacity by making it necessary to hold the doors open longer in cleaning the fire; and in case the ash fuses and runs onto the grate bars, the air is shut out, the grates may be burned, and the results affected by the imperfect air supply. A large percentage of ash tends to make the distribution of air through the fuel bed uneven, requiring a much larger air supply than is necessary for other coals. Large quantities of ash also cause a loss of unburned coal due to the poking and frequent cleaning of the fire. When the coal contains a high percentage of ash, the labor of feeding the furnace with the extra quantity of fuel, the cleaning of the fires, and the handling of the ash, may make it necessary to employ extra help in the boiler room. There is also an additional expense in hauling the refuse away from the plant. The extra quantity of ash may make it impossible to burn a sufficient quantity of coal upon the grate surfaces provided, requiring the operation of an additional boiler. This causes a further loss due to extra labor, radiation losses from the boiler, etc. However, with moderate quantities of ash in the coal, no serious loss should result when the furnace is properly handled.

The Influence of Sulphur.—There are not sufficient data at hand to discuss in general the effect of sulphur in coal. There are coals from certain fields that usually give trouble when the sulphur is high. This is due not only to the sulphur in the coal, but to the combinations of iron and other elements with the sulphur, and the sulphur is merely an indication of probable difficulty that may be experienced. When sulphur occurs in combination with iron, the grate bars are often attacked and seriously damaged, requiring expensive renewals of ironwork.

In general, it may be said that a furnace can be designed to burn almost any kind of coal with good efficiency, and that the real value of a coal depends very largely upon the number of British thermal units which it contains. Tests which have been made at the Government Fuel-Testing Plant seem to indicate that the most important thing to be considered in a coal is its heating value. Following this, the size of the coal may be considered as

next in importance, and when the moisture, volatile matter and ash are widely different they must also be considered. The results of more than 400 boiler tests at the Government Testing Plant show that the average drop in efficiency for a range of coals between 14,000 B. t. u. and 10,000 B. t. u. is only about 6 per cent. This difference is due to the combined influence of the size of the coal, and the moisture, volatile matter and ash in the coal. It will be seen from these figures that the probable influence of any of these constituents is not as great for hand-fired furnaces as it is often thought to be. With certain boiler equipments in which a considerable overload is necessary at times, the effects of these constituents may be much more important owing to the reduction in capacity which may be obtained, and it is for this reason that when coal is selected for a given plant it is important that the coal supplied should not vary greatly from time to time. Otherwise the fireman may have serious difficulty in maintaining the capacity required, and in burning the coal with good efficiency.

With a furnace which is well designed, there should be a close correspondence between the heating value of the coal and the water evaporated. Small variations in moisture, volatile matter and ash should make little if any difference in the efficiencies obtained.

The size of the coal may influence the results to a serious extent. Small sizes of anthracite coal pack together closely and strong drafts are required to burn them. This results in holes in the fire and a leakage of air in the boiler settings. The loss is often estimated to be at least 10 per cent. This is also true of many of the bituminous coals. Other coals which coke readily, forming a loose bed of fuel, do not show much loss owing to the presence of fine coal, which, however, when too fine causes a loss if carried off from the grate by the draft. With any character of coal there may be a loss of fine coal due to sifting through the grates. That this loss may be large is well known.

The carbon in the ash is an important item in determining the losses in a boiler room. In many plants care on the part of the firemen has reduced this loss to the equivalent of 2 and 3 per cent. of the fuel fired.

Occasionally owners of power plants have purchased for testing purposes a coal of higher grade than they usually furnish

for the boiler furnaces. The results obtained have often been disappointing and without further investigation they have declared that the plan of purchasing coal on the basis of its heating value is at fault, and that corresponding results can not be obtained from the higher grade coals. On the other hand it has happened that others have tried coals of lower heating value than the coal regularly burned in their plant, and they often find a greater drop in the evaporation than they expected. This has led many people to believe that there is a great difference in the value of coals for only slight variations in the composition.

A boiler test is a rather crude method of comparing coals, especially if the fireman is not accustomed to burning the coal

TABLE V.—RELATION BETWEEN B.T.U. IN COAL AS FIRED, THE CONSTITUENTS OF COALS, AND THE RESULTING EFFICIENCIES.*

Number of Tests Averaged.	B. t. u. per lb. Coal as fired.	Moisture Calculated to Coal free from Ash and Moisture, per cent.	Ash in Dry Coal, per cent.	Volatile Matter. Coal free from Ash and Moisture, per cent.	Evaporation from and at 212° F. per lb. of Coal as fired, per cent.
5	10,559	16.54	15.41	46.00	6.51
10	11,226	13.49	13.16	44.52	7.23
16	11,728	9.49	12.75	39.57	7.94
11	12,892	5.23	10.52	39.22	8.84
12	13,867	3.64	6.54	36.94	9.60
2	14,554	2.36	4.36	34.44	9.93

to be tested. A chemical laboratory test is conducted under conditions which may readily be duplicated and the results are therefore more reliable than boiler tests.

The averages of a number of boiler tests of each coal, the combustion of which is fairly good in each case, should show results which agree quite closely with those of the chemical tests, provided the coals are of the same general character. If they vary in composition, a slight reduction in efficiency may be expected for the coals high in moisture, volatile matter, and ash.

Table V and Fig. 1 are results averaged from a number of tests reported by the United States Geological Survey, and they show that in general the heating value is a reliable indication of

* Taken from Reports of Tests by U. S. Geological Survey.

the evaporation which may be obtained. The coals of lower grade give slightly lower results. These results are not corrected for the influence of the air supply, the coal lost through the grates into the ash pit, or the heat required to evaporate the moisture in the coal, some of which contained a high percentage of water.

In purchasing coal for any plant, it is essential to first study the possible sources of coal, the general character of the coal available, and the prices at which it may be delivered; after this information is at hand, a coal should be selected which may be

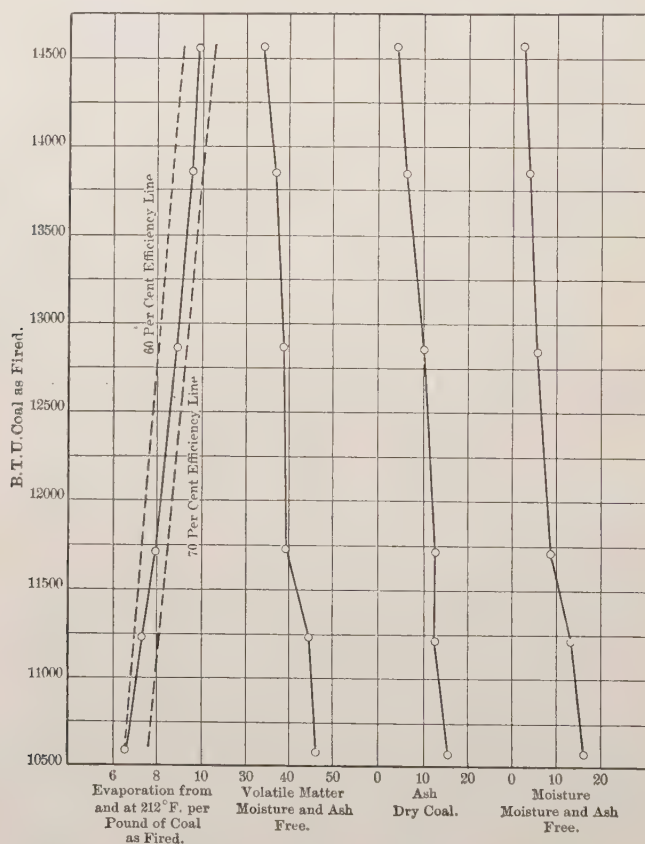


FIG. 1.—Chart showing Relation between Heating Value and Evaporation.

expected to produce a given amount of steam for the least money when all items are considered. This involves the heating value of the coal, its size, its chemical composition, the cost per ton, the kind of grate and furnace, the load to be carried, and the labor and the maintenance cost for the equipment. These will all influence the choice of the coal.

When the character and size of the coal have been selected to give the best results in the furnace installed, its purchase should be made on the basis of a definite contract, in which the character, size, and heating value are guaranteed and provision made for changes in the price above or below the standard for better or poorer coal.

Failure to secure results from coals of the same size in proportion to their heating value is usually due to the methods of firing, provided the furnaces are of good design. The draft required for one coal may not be suitable for another coal, and changes in the thickness of fire, the draft, and even in the methods of handling the fires, may be necessary to secure good results.

Good results may be obtained with almost any coal provided careful attention is given to the conditions under which it is burned. Few plants are doing as well as they should and the opportunities for saving in the cost of producing power are much greater in the boiler room than in the engine room.

Conclusion.—Coals which will give the best results for the least money should be purchased.

If the furnaces are not adapted to the cheaper coals, it may be advisable to change them in order to use these coals.

When the general character of the coal and a suitable size have been decided upon, then the particular coal having these qualities and containing the greater number of heat units for a given price should be purchased.

A contract for coal should provide for the delivery of coal of a certain character and heating value, and should state definitely what changes are to be made in the price for variations in the coal from the standard.

After coal of a specified grade is delivered, it should be burned under favorable conditions, which may best be determined by suitable instruments in the hands of a person trained in their use and the interpretation of the results obtained.

DISCUSSION.

- The President.** **THE PRESIDENT.**—In order to start the discussion I should like to ask Mr. Randall what knowledge there is on the subject of whether the moisture in the coal adds to or diminishes its efficiency.
- Mr. Randall.** **MR. D. T. RANDALL.**—It is generally believed that the moisture is a bad thing, that it absorbs heat at a time when it should be given to the boiler; or, in other words, the heat employed in evaporating the moisture lowers the temperature of the furnace, and reduces the range of temperature available to the boiler. It is very desirable to have as high a furnace temperature and as low an outlet temperature as possible in order to get the heat from the coal. Moisture also holds a large amount of heat that escapes from the stack at about 500° F.
- Mr. Custer.** **MR. E. A. CUSTER.**—Given a furnace adapted to consume the gases, what would be the effect of dissociation of this water, presumably making a gas that would again help in raising the heat?
- Mr. Randall.** **MR. RANDALL.**—We have been besieged for the past two or three years by a great many inventors on that same basis, that one can introduce steam into a furnace and break it up into its elements. Then one would have some hydrogen to burn and consequently there would be a gain in efficiency; but as nearly as I can find out it takes as much heat to dissociate the steam as is generated when it is burned. Therefore it is difficult to find any particular advantage in the method, although I do not pretend to speak as an authority on the subject.
- Mr. Wickhorst.** **MR. M. H. WICKHORST.**—The principle that Mr. Randall has brought out in his paper, that the efficiency is not dependent upon the heat units in the coal, is an important one. It has been the general opinion, I think, that as the heat units in the coal dropped the efficiency also dropped. In locomotive tests we thought we had noticed that result, although the work we have done along that line has not been sufficient for devising a law either one way or the other.

MR. RANDALL.—I should like to call attention to the fact Mr. Randall. that the results presented were obtained on two specific boilers. One was a house-heating boiler, of a kind used for making steam for heating. This I consider a very poor type of furnace. I should regard a locomotive as a poor type of furnace for the same reason, namely, that it has iron sides and a small combustion chamber. The other was a hand-fired furnace with a large combustion chamber giving room for the burning of the gases driven off from the coal. We burned coals containing 25 to 30 per cent. of ash. When there is excessive ash it is nearly always necessary to admit more air than with better coal, and with that larger quantity of air more heat is carried up the stack. A large percentage of ash does reduce the efficiency to some extent.

MR. WICKHORST.—I want to stand up for the locomotive. Mr. Wickhorst. It seems the locomotive has a bad reputation as being an inefficient steam producer; yet, as a matter of fact, I do not believe that is true. We can easily get an efficiency of 70 per cent. from a locomotive boiler until we reach very high rates of evaporation. As long as we keep the evaporation below about 10 or 12 lbs. of water per sq. ft. of heating surface, which is about two or three times what the stationary boiler ordinarily gives, we get an efficiency of approximately 70 per cent.

THE PRESIDENT.—I should like to ask Mr. Randall as to the The President. amount of coal used per hour per square foot of grate surface.

MR. RANDALL.—In the house-boiler tests only 6 or 7 lbs.; Mr. Randall. with the hand-fired boiler as high as 18 or 20 lbs. for the low-volatile coals, and about 25 lbs. for the 44-per cent. volatile coals.

MR. G. B. KOCH.—At the highest rate of combustion in a Mr. Koch. locomotive boiler we burn, or perhaps I had better say fire, from 140 to 150 lbs. of coal per sq. ft. of grate surface per hour. The best results are obtained with a coal which is very high in volatile matter, while the results are not so good with a coal which is very high in British thermal units. Now this may be because the coal which we used in our tests was of a very friable character, such as Scalp Level or Pocahontas, and although it is also very high in heat units and in carbon, we get very poor results. Using this sort of coal with a freight locomotive, we do not obtain an equivalent evaporation of more than 12 to 12.5 lbs. per sq. ft. of heating surface per hour. Using a high volatile-coal we have

Mr. Koch. obtained an equivalent evaporation as high as 16.5 or 17 lbs. With an Atlantic type passenger locomotive, results as high as 18 or 18.5 lbs. have been obtained. All our calculations for heating surface are based on the inside area of the tubes.

Mr. Job. **MR. ROBERT JOB.**—I should like to ask whether the use of steam in boilers in contact with the fuel has been found to be the cause of the pitting of the flues? A case came under my observation not long ago in which two boilers were using the same coal, the only known difference being that steam was blown in under the grate in the one boiler and not in the other. A very decided difference was found in the extent of corrosion of the flues. In the case where the steam had been used marked pitting had resulted.

Mr. Christie. **MR. JAMES CHRISTIE.**—There is much diversity of opinion regarding the most economical practice of burning bituminous coal, whether it should be used as dry as possible or thoroughly wetted. I have in mind two instances of large consumers, one of whom keeps the fuel dry, while the other saturates it with water, each claiming from experiment that his practice gives the best results. It happens that the one favoring dry fuel uses lump coal, whereas the other uses slack, or run-of-mine coal which is largely slack. It is possible that the character of the fuel used accounts for the difference in the results claimed. The lump coal remains in the furnace until it is coked and consumed. Some of the finer particles of the slack coal, if used dry, might be wafted forward by the draft unconsumed, whereas if moistened they cohere until coked; hence the combustion may be more complete than if handled in a dry state. It is known that a similar loss sometimes occurs in ordinary furnaces in attempts to burn pulverized fuel in suspension.

The President. **THE PRESIDENT.**—The Pennsylvania Railroad burns 30,000 tons of coal a day. It is quite evident that a small saving on that amount would mean a great deal of money in a year. No doubt a great deal of that coal is wastefully burned. In fact we know it is wastefully burned through careless firing. Some time ago one of our road foremen was riding on a locomotive with a fireman and he found that the habit was to fire four shovels of coal for each firing; the foreman said to the fireman, "Would it not do as well with three?" The fireman replied, "I do not know, I will try it," and he made the rest of the run with three without difficulty. Apropos

of Mr. Randall's remark that any coal will give good results in a properly designed boiler, I think that is eminently true; but unfortunately after you have your locomotive on the road you cannot re-design the boiler to fit the successive changes of coal. You have to change coal more or less because the element of transportation is a very important one, and you must take the coal through the region that you run in. So that how to really burn coal successfully, and the still broader problem which our Committee on Coal Specifications is attacking, namely, how to make specifications that will enable the consumer to get what he pays for and the producer to get paid for what he furnishes, is a very difficult and complicated one. The President.

MR. RANDALL.—I want to set myself right with those who are interested in locomotives. I did not mean to say that a locomotive is bad as a whole, but that the furnace of a locomotive is of bad design. The boiler is well designed to secure efficiency; it is better and gives a higher efficiency than most of our stationary boilers. With the combination of a poor furnace and a good boiler, the results under ordinary conditions are often as good or better than from a stationary plant. In speaking of burning all kinds of coal in a locomotive, it should be remembered that on any furnace with the same draft 50 per cent. more Pittsburg coal can be burned than Pocahontas or similar coal. Consequently, when burning a volatile coal, more capacity can be obtained from the equipment. No doubt with a strong enough draft the rating may be obtained with Pocahontas coal, but the draft will carry a great deal of the coal off the grate that does not burn at all, and may thus cause a drop in efficiency below that for some other coal of lower heating value. Such results are due to faults of the furnace or the operating conditions and are not chargeable to the coal. Mr. Randall.

THE STANDARDIZATION OF EXPLOSIVES.

BY CHARLES E. MUNROE.

Although many materials have been brought to the attention of this Society as being worthy of its consideration, and of these most have been deemed of sufficient importance to be assigned as topics for investigation and report, few are of so fundamental a character or admit of such wide and varied applications as explosives, since they constitute a most powerful and, if properly made and used, a most efficient source of available energy, while moreover it is possible to so modify them in composition, physical condition, and environment, as to obtain almost any desired degree of effect, within limits. It is not surprising therefore that they have met with continually increasing use by the military and naval engineers in weapons of offense and defense, in torpedoes and mines, and in the removal of obstacles to navigation; by the mining engineer, in sinking shafts and driving galleries, in the winning of ores, oil, and coal, and in the quarrying of rock and stone; by the civil engineer, in excavating cuts, making fills, driving tunnels, uprooting stumps, sinking piles, destroying boulders and preparing sites for buildings or reservoirs, or pathways for railroads, highways, canals, aqueducts, pipe lines or other means of transportation or communication; and by the metallurgical engineer, in breaking up masses of metal, the removal of obstructions in furnaces, and the demolishing of stacks.

This somewhat extended narration does not cover all of the many uses to which explosives have been advantageously applied. Moreover, new applications are quite frequently being made and the benefits resulting from these uses have been so continually made manifest that the manufacture has steadily increased, until in the census year 1905 there was produced in the United States alone 363,748,097 lbs. of explosives and it is safe to say that the production abroad was quite equal in quantity.

This census report embraces all the varieties of explosives regularly manufactured. For some 500 years gunpowder was the only explosive at command. During the latter part of the

eighteenth century, suggestions began to arise as to utilizing other substances as explosives and these propositions took substantial form in 1800, when mercuric fulminate was presented by Davy, and more especially since 1845, when attention was first called to the nitric esters to which chemical class the powerful explosives nitroglycerin and the cellulose nitrates belong. Since that time the invention of new explosives by utilizing the nitric esters, the nitro-substitution compounds, and the nitrates, chlorates, perchlorates and other oxidizing agents in admixture with one another and with other combustible and oxidizing substances, has gone on at such a rate that more than a thousand different, or differently named, explosives have been offered for use, and the number is being steadily increased, though but a few of these compositions have stood the test of experience and become regular merchantable articles.

As pointed out, the effect which any given explosive will produce, other things remaining the same, will vary with the composition or with the physical condition of the explosive, and it may be safely asserted that no two different compositions will give identical results. Notwithstanding, then, that man has in explosive substances a very powerful and yet sensitive agent, with the exception of the specifications of ballistic powders which have obtained for some time, nothing has been done in these centuries towards standardizing explosives, except that in very recent time a few consumers have purchased on analysis.

That some definite standard of composition is needed for explosives offered on the market may perhaps be made apparent by instancing dynamite. As invented by Nobel it consisted of an absorbent, called a dope, and nitroglycerin. The absorbent long used commercially was kieselguhr, known also as infusorial silica. It was made to absorb and hold various percentages of nitroglycerin up to 75 per cent. of the dynamite produced, and the product was styled by a name such as 75 per cent. dynamite, which indicated the quantity of nitroglycerin contained in it. Kieselguhr is incombustible, so it and substances like it that were used as absorbents were called in explosive dopes. Nobel also found, however, that gunpowder or gunpowder-like mixtures, such as wood pulp and nitrate of soda, would act as satisfactory absorbents for nitroglycerin, and hence a large number of dyna-

mites have been made and used with these explosive dopes, but since there has been a dispute as to any useful explosive effect from the dope, these dynamites have been generally rated by their nitroglycerin content only.

Later it was discovered that explosives such as the cellulose nitrates, which, like nitroglycerin, can be made to detonate, could form compositions with nitroglycerin, and such compositions, or others with nitro-substitution compounds mixed with a dope, have been offered in the market as 40 or 60 or other per cent. dynamites, though they contain less than the designated percentage of nitroglycerin. It is claimed by the manufacturer that the new compositions are as strong as a straight dynamite containing the designated percentage of nitroglycerin. This may be true for a certain set of conditions; in fact, the new composition may be under certain circumstances not only as efficient as the straight dynamite, but under other circumstances even more efficient. Nevertheless the consumer is entitled to know definitely by some conventional means the nature and composition of an explosive which is publicly offered for sale, in order that he may decide for himself when and how he shall use it and a reasonable price to pay for it.

As another example one may cite black blasting powder which, as invented in 1857 by LaMotte DuPont, is a mixture of charcoal, nitrate of soda, and brimstone. This has been most extensively used in mining in this country, particularly in coal mining, so that at the census of 1905 the production amounted to 205,436,180 lbs.; yet to-day no standard exists as to the kind of wood from which the charcoal is to be made, the manner in which and the degree to which it is to be "burned," the proportions in which the components of the powder are to be mixed, the conditions and extent of incorporation, or the quantity of moisture which may be left in the finished grains. Neither have any steps been taken until recently to insure uniformity in granulation, although this feature is of vital importance and its effect well known.

As a third example the classification of detonators, known also as blasting caps, may be mentioned. These powerful and delicate initial sources of detonation have been graded by a variety of methods at the will of the manufacturer, whereas the vital infor-

mation which the consumer should possess is a knowledge of the quantity of fulminating composition contained in each capsule. The system of grading should therefore be so conventionalized as to set this forth explicitly.

There has arisen in recent years much dissatisfaction on the part of consumers as they have come to inquire into this matter and discovered the conditions which exist. This has been particularly the case with regard to blasting powder. The mine inspectors in several of the states have taken up the inquiry and it has been experimentally examined into by the Technologic Branch of the United States Geological Survey at the Pittsburg Testing Station. The Bureau of Explosives of the American Railway Association has also been making investigations into the composition of commercial explosives, particularly as it affects safety in transportation. But there is a broader field to be covered which neither of these organizations deals with, and which no individual is likely to undertake, and I believe that this offers a proper opportunity for useful service by this Society.

DISCUSSION.

Mr. Dunn. **MR. B. W. DUNN.**—It is evident that the manufacture of explosives is of great interest and importance to all constructing enterprises in the country. One reason why this body, in preference to any other, should take it up will appear when we examine our form of government as relating to this matter. If our government were similar to that of England or Germany, the proper and safe method of manufacturing explosives would be prescribed legally. This cannot be done uniformly here on account of federal and state jurisdictions. Being an industry, the regulation of the manufacture of explosives naturally falls within the province of the State. You can appreciate the difficulty of getting uniform regulations when the number of our states is considered. Since we cannot get proper legal regulation, we must get results through voluntary cooperation. There must be some body such as this Society to take the lead.

The necessity for regulation is patent. Just remember that under present conditions anybody is free to go out into the woods in any locality and begin the manufacture of what he may choose to call dynamite. If he can succeed in getting customers to buy it and believe in his claims for its safety, power, and value, no one else seems to be concerned. That is not the way in which the matter should be regulated. I have reason to know that many of these manufacturers would be very glad indeed to have some well-informed committee, such as can be formed in this Society, consider the subject and draw up a set of standard specifications which would be of great value to them in standardizing their products. The safety of the country is involved in many ways, because these explosives, if not made properly, may deteriorate rapidly. Nitroglycerin may readily exude from dynamite if the proper absorbent is not used, and when it does exude it lays a foundation for trouble. In connection with my duties as Chief Inspector of the Bureau of Explosives of the American Railway Association, I have had occasion to point out to manufacturers inherent faults in the composition of their explosives, and in one

case have been finally able to demonstrate the correctness of a **Mr. Dunn.** scientific prediction.

This committee would cover such points in drawing up a standard set of specifications. I do not think it is necessary to say anything else in support of such an evidently reasonable proposition.

MEASUREMENT OF IMPACT STRESSES.

BY B. W. DUNN.

The writer's limited experience includes two attempts to measure the maximum intensities of rapidly changing stresses, and a brief statement of the two problems, the methods adopted for investigation, and the results obtained, may be of some interest to the members of this Society.

The time required for powder-gas pressure in a gun to rise to its maximum varies with the caliber of the gun and with the conditions of loading. It is expressed in thousandths or, at most, in hundredths of a second. It is measured by noting the set which it causes in the length of a small copper cylinder and translating this set into pressure per square inch by a tarage table constructed from static testing machine data. This assumes that the set is independent of the time of application of the compressive force. Similar sets can be produced, in approximately the time consumed in the gun, by the blow of a falling weight, and the problem was to measure the varying resistance of the copper to the blow. Without special apparatus, our data would be limited to the energy in the blow and the path, from which only the mean resistance of the copper could be calculated.

The principles involved in the dynamic measurement of forces are extremely simple, but their practical application involves difficulties. Empirical curves must be recorded in which the abscissas represent time consumed and the ordinates distances traversed by a known mass under the action of the force to be measured. These elements are small, and however smooth our curve may appear to be, irregularities will abound when we come to plot its first and second differences.

In the apparatus devised to investigate the copper cylinder problem, photography was used to record the impact curve and the time scale on the surface of a cylinder revolving uniformly with a surface velocity of about 100 ft. per second.

Those who may be specially interested are referred to the *Journal of the Franklin Institute*, Vol. 144, No. 863, November,

1897, and to the discussion in the same journal, Vol. 145, No. 1, January, 1898.

CAR IMPACT TESTS.

Another problem of this general nature was presented more recently as one feature of the work of the Bureau of Explosives organized by the American Railway Association to promote the safe transportation by rail of explosives and other dangerous articles.

What maximum pressures are exerted on packages loaded in freight cars as a result of coupling and other shocks incident to transportation, and what are the most practicable methods for loading and bracing packages in the cars to minimize the effects of these shocks?

Many thousands of dollars are sacrificed monthly by damages to railway freight, and when this freight is of an explosive nature loss of life, as well as of property, may result.

The accompanying illustrations show some of the methods in general use for loading and bracing packages of explosives in freight cars. Four hundred boxes of dynamite, about 24,000 lbs. gross weight, or 1,000 kegs of black powder, about 28,000 lbs. gross weight, constitute the ordinary car load; but occasionally a car is loaded with 60,000 to 70,000 lbs. gross weight of explosives. When practicable, the packages are confined to the ends of the car, and they are piled to interlock so that a bracing of the front row will secure the entire shipment against relative longitudinal movement in the car.

Fig. 1 shows the method of loading boxes of dynamite in the end of the car. Alternate tiers are blocked up to secure interlocking so that the floor brace nailed to the car floor in front of the first row of 8 boxes prevents relative movement of the entire load in the direction of the length of the car. The 8 boxes must be strong enough to transmit the total pressure to the floor brace, this pressure being proportional to the number of boxes in the load. Twelve thousand pounds of dynamite may be loaded in one end of a standard box car.

Fig. 2 shows black powder kegs loaded, interlocked, and braced as illustrated by Fig. 1 for dynamite boxes. Over 13,000 lbs. of black powder may be loaded in one end of a standard box car.

Fig. 3 shows a side view of a full carload of dynamite through an open car-door. The boxes are not interlocked and the open space at the center, after loading from the ends toward the center, is filled by wooden frames separated by four wedges. A standard box car containing 60,000 lbs. of dynamite loaded in this way made a trip recently from Emporium, Pa., to Birmingham, Ala. An explosion of such a load would have a destructive effect on buildings within a radius of about 600 yds. A vivid imagination is not needed to appreciate the grave and unwelcome, but necessary, responsibility that rests on shipper and common carrier in the interests of public safety.

Fig. 4 shows an interior view of one end of a carload of black powder. The kegs are not interlocked and the load is braced by wooden frames separated by 8 tightly fitting 2- by 4-in. struts. The usual limit to a full carload is 2,000 kegs containing 50,000 lbs. of powder.

Fig. 5 shows the deformation of black powder kegs by abnormally severe coupling shocks.

Fig. 6 shows an interior view of a car loaded with dynamite after an accidental collision with another car loaded with dynamite. Eleven boxes at the impact end were crushed or seriously damaged and it is fortunate that an explosion did not occur.

In Fig. 1, the 8 boxes in the front row may be required to furnish the resistance necessary to prevent relative motion in the 232 boxes that may be loaded by this method between this row and the end of the car; and in Fig. 2, the 11 kegs in the front row may have to hold 557 kegs. In order to analyze the efficiency of any package or method of bracing, therefore, we must know the resistance per unit weight, expressed as a function of speed at impact, required to prevent relative movement.

Some preliminary tests, designed to furnish this information, were made at the writer's request by the Pennsylvania Railroad at Altoona. Mr. A. H. Elliot was specially assigned to the work under direct supervision of Mr. E. D. Nelson, Engineer of Tests. If time and cost could have been neglected, a time-space curve for the car during impact, similar to that obtained for the copper cylinder in the first problem, would have been made. This being impracticable, recourse was had to the use of a steam indicator gauge for a direct measure of the unknown pressure. This gauge

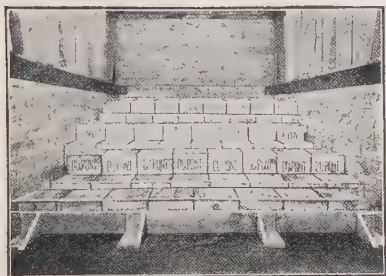


FIG. 1.



FIG. 2.



FIG. 3.



FIG. 4.



FIG. 5.

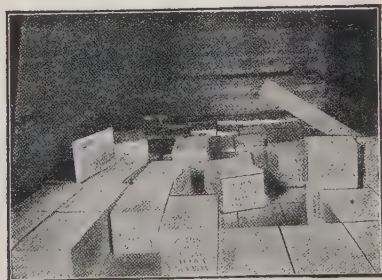


FIG. 6.

was used, first, to measure hydraulic pressure due to "retardation" of a known mass, and second, to retard a known mass by direct resistance of the gauge spring.

Hydraulic Apparatus.—A 3-in. pipe, 30 ft. 10 ins. long, was secured rigidly to the sills of a steel underframe car of 100,000 lbs. capacity. The pipe was filled with water, care being exercised to remove the air, and the gauge was connected at the impact end. The car was allowed to run down a grade under gravity and

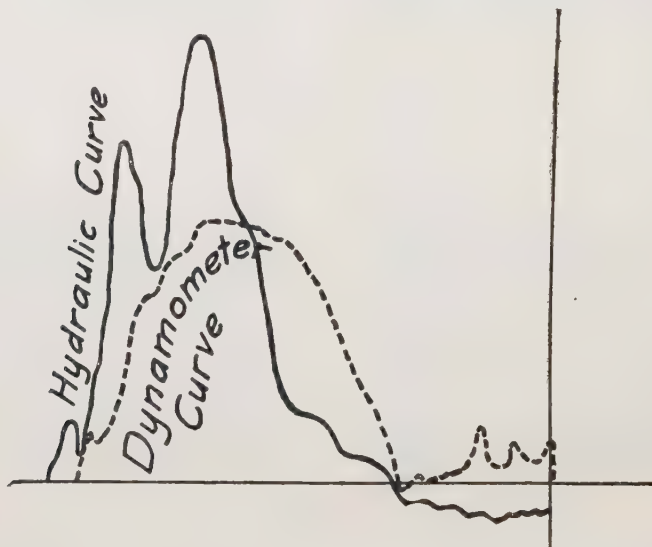


FIG. 7.—Test No. 301, Cards No. 10. Both cards taken at same time. Springs.—80 lbs. per inch. Velocity.—5.1 miles per hour.

collide with a draft of loaded coal cars whose air and hand brakes were set. This made a solid "bumping block" and limited the working path practically to the compression of the friction draft gears of the colliding cars and to such additional elastic compression of the car frames as was necessary to absorb the energy. The speed at impact was carefully measured and the calibration of all gauge springs used was verified. The gauge registered the maximum pressure in pounds per square inch required to retard the liquid mass. The maximum pressure exerted per pound of this mass was plotted as a function of the speed in miles per hour.

The cards showed a rise and fall of pressure and several successive maximums due to reaction of the springs and a wave motion in the liquid.

Dynamometer.—The gauge was mounted horizontally, and a solid mass equal in weight to the active column of liquid rested against the piston and was retarded directly by the resistance of the gauge spring. Simultaneous observations were taken with the two forms of apparatus, with draft gears in service, and tests were made with the dynamometer under abnormal conditions obtained by throwing the draft gears out of service. Maximum pressures under these circumstances were high for low speeds.

The average results are shown in Table I.

TABLE I.—AVERAGE RESULTS.

Speed in Miles per Hour.	Maximum Pressures per Pound of Mass Decelerated.		
	Friction Draft Gear.		
	In Service.		Out of Service.
	Hydraulic.	Dynamometer.	Dynamometer.
2.8	.....	.....	10.68
3.2	.....	.....	12.19
3.6	.....	.....	15.30
4.0	7.20	5.09	.....
5.0	10.60	6.82	.....
6.0	18.03	.....	.....

Fig. 7 shows superimposed records made simultaneously with the two forms of apparatus. The dotted dynamometer record of maximum pressure is lower than the hydraulic record. The area under these curves does not represent work.

The curves in Fig. 8 show the average results. For speeds not used in the tests the curves are dotted.

According to published laboratory results obtained with a static testing machine, each of the two Westinghouse friction draft gears in collision was able to absorb about 18,000 ft. lbs. of energy without exceeding a maximum resistance of 180,000 lbs., or about 3.9 lbs. of resistance per pound of the empty car. An energy of 36,000 ft. lbs. in this car corresponded to a speed of 4.8 miles per hour.

If the above measures of impact stresses are reliable, it appears that these friction draft gears are capable of offering resistance to compression greater by from 70 to 150 per cent. when acted on by a blow rather than by a slowly applied pressure. From

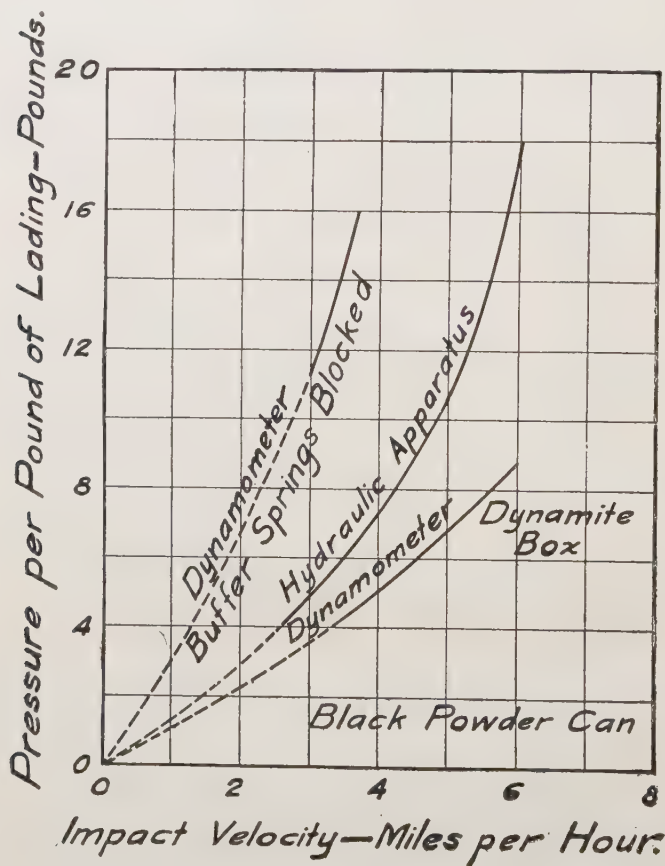


FIG. 8.—Car Impact Tests by the Pennsylvania Railroad.

our knowledge of the construction of these gears it does not seem unreasonable that the friction wedges should offer higher resistances to rapid motion.

It was to be expected that the hydraulic would exceed the dynamometer measurements. In the latter the entire movement

of the gauge spring is added to the working path for the test weight. In the former the spring movement is followed by liquid from the 3-in. pipe whose area of cross section is fourteen times the area of the gauge piston. The column of liquid acting on the piston moves only one-fourteenth of the distance that a solid mass would move for the same spring compression.

The serious stresses exerted on packages contained in freight cars that are allowed to collide at a speed as high as 4.8 miles per hour, will be evident even if we take the pressure of 3.9 lbs. per pound of lading calculated from laboratory tests of the friction draft gear. In Fig. 1, the 8 boxes of dynamite in the front row would have to resist a total pressure of 47,970 lbs. after correction for friction of the boxes on the car floor. If we accept the hydraulic measures, this total would become 126,417 lbs., or 15,802 lbs. per box. The ultimate strength of a box under the crushing and shearing conditions is about 12,000 lbs. and ruptured boxes are discovered in cars from time to time.

In Fig. 2, the 11 cans must resist a total pressure of 45,240 lbs. if we take the value calculated from the friction gear; or a total of 137,300 lbs., 12,480 lbs. per can, if we take the hydraulic measure. The ultimate strength of a can under the best conditions is less than 2,000 lbs., but as shown by Fig. 5, they will stand excessive deformation without rupturing or allowing powder to escape. We derive little comfort, however, from the fact that when a powder car gets what railway employees regard too frequently as normal treatment the kegs may escape with nothing worse than deformation. Deformation means pressure on the powder and a rapid grinding of the grains over each other not conducive to safety.

It is believed that the results of these preliminary tests should cause a further and more complete investigation of this important subject. We have at least demonstrated the necessity for the greatest possible care in coupling and handling freight cars. Enforcement of this care would avoid many of the daily injuries to railroad equipment and freight. In these injuries we see the principal penalty paid for the advantages of the automatic coupler and of the "hump" in the rapid assortment and classification of cars.

THE DESIRABILITY OF STANDARDIZING THE TESTING OF INSULATING AND OTHER MATERIALS.

BY C. E. SKINNER.

Two passengers on a transatlantic steamer, both utterly worn out from weeks of preparation in the heat of summer for an extended trip, one representing a manufacturer of insulating materials, and the other a user, were reclining in their steamer chairs some little distance apart, the first day out from New York. The representative of the consumers suddenly became interested in a very promising insulating material in the calking of the seams in the deck, and immediately applied the universal test for such materials, viz., the application of the finger nail. While in the act he happened to glance at his companion and found him engaged in identically the same occupation. A laugh followed, and it was recognized that the ruling passion could not be avoided, even in mid-Atlantic.

In the test applied both formed a definite idea of the physical characteristics of the calking material, but neither could describe these characteristics, except in the most general terms. Even with the facilities of their laboratories at their command, they would have had to enter into more or less elaborate explanations as to testing methods, as well as results, before they could have given figures which would be intelligible to each other. This incident serves very well to illustrate the main theme of this brief dissertation on the desirability of standardizing the testing of insulating and other materials.

The subject is so broad that it is difficult to decide what point of view should be taken, and what materials should be included as examples. It is so self-evident to the speaker that we have every reason for standardizing our testing methods, and no reason against it, that argument on the point seems superfluous. The difficulty probably does not lie so much in the fact that as engineers we do not desire the standardizing of our testing methods, as in the fact that it requires time and thought and

labor to secure such standardization, and it is therefore usually easier for the individual to adopt his own standards rather than trying to line up with the standards of others. Even when a firm or an individual adopts his own standards of testing, these are rarely known to others, and as more and more work is done it becomes harder and harder to change to some other method or some other standard, even though it is equally satisfactory as far as actual results are concerned. All previous data are based on a specific set of methods and testing apparatus, and in making a change to a general standard it becomes necessary to have some means of interpreting one's own work in the light of previous tests.

The testing of insulating materials for electrical purposes is comparatively new to the art, dielectric tests, for example, dating back not more than twenty years at the outside. All electrical machinery is composed essentially of three factors—conducting material, magnetic material, and insulating material. We might add structural material as a fourth factor, but this is almost invariably integral with or extensions of the magnetic material.

The conducting material used is almost invariably copper. Certain essential tests have been worked out to a very high degree of accuracy, and standards have been adopted such that when the conductivity of any material is given in per cent. those familiar with the art immediately have an exact conception of what is meant. There are other qualities of the conducting material, such as hardness, flexibility, etc., which are not so well known, but for which it would be very desirable to have some definite measure. The Committee on Specifications for Copper of the International Association for Testing Materials is devoting a good share of its energies to testing methods.

Magnetic material, which is universally iron, or steel in some of its forms, has been very carefully studied, and definite means of measuring permeability, hysteresis, eddy current loss, etc., have been established, though not standardized as in the case of the conductivity of copper. Our Society has a committee at work on this problem, and it is hoped that definite standards may be evolved and adopted throughout the country for the measurement of the essential qualities of the magnetic material which enters into the dynamo-electric machinery.

In the case of the conducting and the magnetic material, it should be noted that only one material need be considered in each case. With insulating material, the problem becomes far more complicated on account of the fact that insulating materials are almost invariably chemical compounds instead of chemical elements, and are presented in almost infinite variety. In the early work in connection with electrical machinery and apparatus, insulation and insulating materials were given only secondary consideration, and this, combined with the very great variety available, has resulted in there being very little in common in the testing methods followed by different companies and different interests. In common with conducting and magnetic materials, however, they have certain essential qualities which must usually be determined in each case, no matter what the form of the material. These are—insulation resistance, dielectric strength, and specific inductive capacity.

On account of the wide variety of physical conditions presented by the various classes of insulating materials in use, physical tests and chemical determinations are also often necessary. We have, for example, insulating material with physical characteristics ranging all the way from light liquids through the paints, varnishes, pitches and gums, to the fabrics, papers, molded compositions in almost endless variety, and ending in the minerals, such as mica, asbestos, and artificially formed refractory materials, such as porcelain.

Each general class of materials will require its special means of determining the qualities which must be known to properly understand the grade as compared with any other material of the same general class. It is probable that in many classes sufficient work has not yet been done to allow such standardization, but in some of the classes the data should be sufficiently complete at the present time to allow the standardization of the testing methods for determining the fundamental characteristics of the materials. For example, it is very generally accepted practice among those who use oil for insulating purposes to make tests for dielectric strength by immersing a spark gap in the oil and determining the electro-motive force required to strike across this gap when so immersed, this test giving a measure of the insulating quality of the oil. There is, however, no accepted

standard for the length of gap, the shape of terminals; the rate of increase of electro-motive force, the limitation of the size of steps in raising the electro-motive force, the number of tests on a given sample, the depth of immersion of the gap in the oil, the temperature of the oil, etc., all of which influence the final results to a greater or lesser extent.

Again, we are confronted with the necessity of testing molded materials in almost endless variety and shape. The tests required for different materials vary to some extent with the use to which they are to be put, but in general it is desirable to know the dielectric strength or resistance to puncture, the compressibility of the material, its brittleness, hardness, ease of machining, fire-proofing qualities, melting point, solubility in different mediums, etc. If standard forms of test samples and of testing methods could be adopted for determining the more important of these qualities, the manufacturer of molded materials could then present to the user a set of tests made by any reputable testing laboratory, with the assurance that these tests would be understood, and at least a preliminary understanding of his particular material arrived at by a mere inspection of the tests. It is not to be expected that such standard tests will satisfy all requirements, as the individual user will often require special tests to determine the fitness of any given material for his specific purposes. On the other hand, standards will allow prospective users to determine in many cases whether or not it is desirable or necessary to go to the expense of making their own special tests.

Another example which might be cited is the testing of insulating materials of the class known as treated fabrics and papers. In this case the dielectric strength, the flexibility, the solubility of the coating in certain materials, such as lubricating oil, which may come into contact with the material in service, are desirable. For example, results of dielectric tests in volts per mill, obtained in various and sundry ways, are presented, and even such results are rarely comparable with those of the prospective consumer unless the exact method of testing be known. The length of time of application of the testing voltage, the shape and area of terminals, the amount of pressure used, the temperature of material at the time of test, and many other

things influence the result. It would seem to be a relatively easy matter to adopt standards for these various essential points in connection with tests of this class.

With many insulating materials, and in fact with many materials outside of the insulating field, there are no testing methods available at the present time which give a satisfactory measure of their desirable or undesirable qualities. In no class, perhaps, is this more true than in materials which might be classed generally as gums, such as the various mineral and vegetable gums and waxes. Each manufacturer and user has his own methods of arriving at an understanding, as by the fingernail test, and much of this is frequently left to someone whose judgment in such matters is due to long training from intimate contact with the uses of the materials in question. Such an individual may deliver a fairly satisfactory judgment in regard to a given material, but it is next to impossible for him, even if he so desires, to give his method of testing to another so that the same judgment would be formed.

Again, it is very easy for one skilled in the testing of mica to determine whether a given sample is hard or soft, or has the necessary flexibility for molding purposes, but up to the present time no means of measuring these qualities have been presented which would give these results in numerical figures. This is also true with many other materials and many other qualities represented in the vast array of insulating materials used in the construction of dynamo-electric machinery.

What has been said in regard to insulating materials is also true in regard to some of the qualities among better-known materials used in industrial work. Many specifications for copper wire, for example, used for windings of electrical machinery, call for the wire to be "dead soft." A skilled winder will make a test for this quality with his bare hands in a few seconds and deliver a correct opinion, but no really satisfactory test is available as a standard to measure whether the material meets the requirement of being "dead soft" or not, this being particularly true in the case of very small wires.

Again, such materials as phosphor bronze, used for springs, receive their spring quality from the amount of cold rolling given after the last annealing. In some cases material is specified to

be rolled ten numbers hard. It is quite a different matter to test such materials with sufficient accuracy to determine whether they have been so rolled, or whether the proper spring quality has been imparted to them. The difficulty is further increased by the fact that the test of materials of this kind must be made in the finished form, as the shape or size of the finished product frequently has a very decided influence on the final result. A standard form of test sample cannot therefore be adopted.

We all recognize the necessity of standards of length, standards of weight, and standards of volume, and yet even these are still subject to long and bitter dispute, for the reason that it would cost the present generation time and money to change to standards which might, perhaps, be better adapted to the needs of coming generations. We have a good illustration in the Congress of the United States not adopting the metric system when it was first presented many years ago, "owing to the expense and confusion which would be created by such a change." If the change had been made at that time, our system of weights and measures would now correspond to that of the countries of continental Europe, and Great Britain would long ago have been forced to adopt the same standard.

It would seem to me to be pre-eminently the function of this Society, and the privilege of its members cooperating through the Society, to bring about the earliest possible standardization of tests and testing methods by which we measure the essential qualities of the materials of engineering. As time goes on, it will be increasingly difficult and expensive to bring about such standardization. That such standardization will eventually be required is very well evidenced by the fact that practically all our national societies have committees on standards of one kind or another, and the older the work the more difficult the standardization becomes. As an example of this might be cited the work of the American Society of Mechanical Engineers in their attempts to standardize machine screw threads. We now have the standards, but they are not universally adopted as yet.

Why should we not do some advance work along the more important lines indicated before individual standards become so strongly intrenched as to make the adoption of general standards

difficult, if not impossible? We could use the Society as a clearing house for methods of testing, giving them such publicity that those beginning such work may be able to use methods already established. By the spreading of information of this kind, and by the standardization of known methods through committee work, we would be able to bring about results such that individuals could understand each other without the necessity of carrying a dictionary of methods.

If, for example, a specific form and dimension of test sample for molded insulating material, and a certain specific method of making dielectric tests, absorption tests, fire-proofing tests, etc., be adopted for such materials, each producer will get the same information that he gets at the present time, but in such form that he can understand the information obtained by anyone else in testing the same class of materials.

In all such work we must, of course, be very careful not to interfere in any way with the natural development of new and better methods or materials, by testing with standard methods which do not adequately show the qualities which we must know. Neither should we place any restrictions on the manufacturer or user who wishes to make tests other than those which may be decided upon as satisfactory standards.

It is my belief that a consistent program of standardization of tests and testing methods carried out by our Society would be a stimulus to the development of new and better methods, and should result in new interest in and growth of the Society.

PRINCIPAL FEATURES OF A 1,200,000-LB. TESTING
MACHINE WITH SPECIAL REFERENCE TO A
NEW SYSTEM OF TRANSMITTING THE
PRESSURE DEVELOPED IN THE
HYDRAULIC CYLINDER TO
THE SCALE BEAM.

BY THORSTEN Y. OLSEN.

During the past year a new type of testing machine has been developed, which marks a step forward in the construction of testing machines of large capacity. This type has thus far been developed primarily for compression tests only.

The main feature of this machine is the new system of transmitting the pressure developed in the hydraulic cylinder to the scale beam. The standard commercial lever testing machine weighs the entire pressure directly on three main levers, from which it is transmitted to the scale beam. The size of these levers, and consequently the size of the machine, is governed to a large extent by the length of the primary knife edges, the pressure on which must not exceed 10,000 lbs. per linear inch. Owing to the size, weight, and consequent cost of weighing systems constructed on this principle, as well as for mechanical reasons, I would limit the capacity of this type of machine to 1,000,000 lbs.

The high cost of large testing machines has limited research work and deprived the engineer of data he now requires. Some large presses have been equipped with pressure gauges and used as testing machines, but this is not altogether satisfactory, since the gauges are neither accurate nor reliable and the readings exceedingly coarse. From a practical standpoint, however, this has been the only means of testing large specimens.

The testing machine I now wish to describe was designed especially for the new Testing Laboratory of Rensselaer Polytechnic Institute of Troy, N. Y., where it is now in successful

operation. In explaining the construction I will divide the machine into four distinct parts:

Press proper.

Pump and motor drive.

Adjustment of upper head.

Weighing mechanism.

Press Proper.—This requires but little description, as in general construction it resembles an ordinary press. The cross-heads, cylinder, piston, and weighing platen are steel castings, while the four tension rods are of 0.40-carbon steel. By thus making all the heavy parts of steel, the weight and over-all dimensions are reduced to a minimum.

To facilitate handling, the cylinder casting is separate from the base cross-head, and the piston is guided by an extension fitting into the base. An important feature of the cylinder is the packing, which is of entirely new design. This form is absolutely tight and distributes the friction uniformly at all points under any loading. The packing is so constructed that the friction necessary to prevent leakage varies directly with the pressure; the friction is therefore eliminated as a factor in the weighing system, and is allowed for in the calibration of the poise on the scale beam.

To obtain an even bearing for the test specimen, the weighing table is provided with a spherical adjustment on the top of the piston.

Pump and Motor Drive.—A uniform application of load is an essential point, especially in a compression test of concrete or like material, and with this in view a special form of pump was designed. It consists of a long steel cylinder in which a piston is driven by means of a screw operated through a series of gears by a direct-connected motor. With this gearing four pump speeds may be obtained. An automatic cut-off is provided at either end of the stroke so the pump can in no way be injured. The pump packing can be quickly replaced.

With one stroke of the pump the press piston is raised $\frac{1}{2}$ in., which is usually sufficient to break any concrete or stone specimen tested. Provision has been made for maintaining the pressure in the cylinder and quickly refilling the pump, in order to provide any additional motion desired.

A 2-H. P. motor will operate the pump to the full capacity of the machine, as well as drive the upper head.

Adjustment of Upper Head.—The four tension rods are threaded at their upper ends, on which are fitted four gear nuts. A ball thrust bearing is inserted at the top of each nut and the upper cross-head suspended from a cover plate resting on them. The four gears are so connected to each other and the source of power, that by operating a hand lever the nuts are rotated

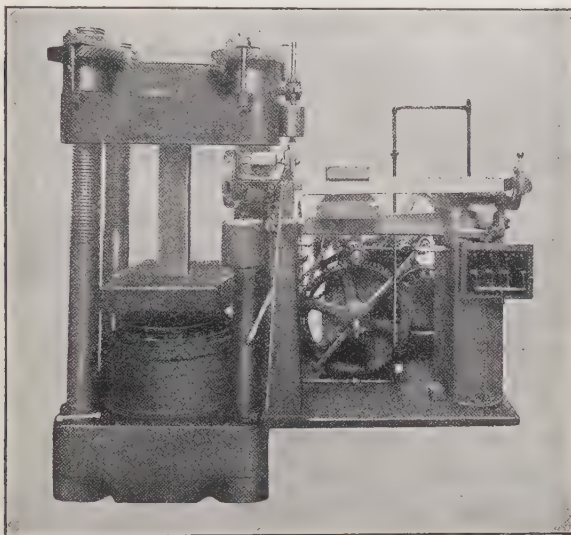


FIG. 1.—Olsen's 1,200,000-lb. Hydraulic Testing Machine.

simultaneously and the cross-head quickly raised or lowered as desired.

The Weighing Mechanism.—The method of weighing the load is of special interest, as it is a departure from previous practice.

The pressure on the piston of the main cylinder is transmitted to a diaphragm, the area of which is one-twenty-fifth of the piston area. The pressure on this diaphragm is communicated to a lever system terminating in a standard dial vernier screw beam and weighed with great accuracy, since the diaphragm is frictionless. The friction in the main cylinder is very uniform and owing

to the type of packing, as mentioned before, is fully compensated for in the method of calibration. The variation of the friction is so small as to be negligible.

Two methods were used to calibrate and determine the accuracy of this machine. The first was that used in calibrating all testing machines to-day: the use of standard levers and weights. The steel levers were of special design, with a count of 20, so that by mounting them in the machine and applying load increments of 50 lbs., a maximum of 100,000 lbs. was readily attained. To obtain great accuracy in the calibration of the poise, and to conform with the conditions obtaining in a test, all the readings and beam balances were noted with the piston in motion. With the poise properly calibrated, the beam weighed with great accuracy all increments of load and was thus proved correct to 100,000 lbs. It would be reasonable to assume the machine correct to the full capacity of 1,200,000 lbs., but to be fully convinced of this fact it was further tested as follows:

A steel specimen 3 ins. square was placed in the machine and readings taken of the deformation for each 20,000-lb. increment. The corresponding increments of deformation were uniform, and the deformation up to 480,000 lbs. was within 0.001 in. of that obtained by testing the specimen in the 600,000-lb. Universal four-screw lever testing machine described before this Society a year ago, using the same compressometer.

As it was not advisable to test this specimen beyond 480,000 lbs., three similar pieces of steel, each with a similar compressometer attached, were tested with the original specimen. Readings were taken for increments of 80,000 lbs., and found to be quite regular up to 1,200,000 lbs. The deformation of the specimens thus tested was within 0.0002 in. of the deformation of the first piece under 300,000 lbs.

These experiments and tests show the accuracy of the weighing system, for which we claim an accuracy exceeding one-third of one per cent.

This machine is also very sensitive, for on testing with the beam in perfect balance the pressure of the hand on the testing table will cause the beam to vibrate. This type of weighing apparatus is as accurate as that of the standard lever testing machine, and lacks but little of the same sensitiveness.

In connection with this machine, let me mention the 10,000,000-lb. compression testing machine of the same general design now under construction for the United States Geological Survey. With the knowledge of what the smaller machine will do, the success of the larger one is assured, and it is safe to predict that it will exceed all expectations as to accuracy. Many novel features have been devised for staying the machine, and for ease of setting and adjusting specimens. Each detail has been studied in order to make the machine as nearly perfect as possible in every respect.

In conclusion, let me say that the testing of full-size structural members is assured. Testing machines far more accurate and reliable than required either in practice or in research work can be obtained at a reasonable cost by this type of construction.

A MACHINE OF NEW DESIGN FOR HARDNESS TESTS.

BY THORSTEN Y. OLSEN.

The hardness test for iron, steel, and other metals has heretofore been used principally in research work in the development of high-grade tool steel, in determining the effects of various processes of case-hardening, etc. It has, however, stepped beyond the field covered by the research laboratory and is demanded for determining the proper material, from the standpoint of machining and finishing, for maintaining a constant and uniform hardness in gearing, such as used in automobiles; for determining the uniformity of wheel tires, so that two tires of the same hardness may be selected and placed on the same axle to produce uniform wear; and a number of other practical applications of this nature can readily be cited.

These tests must be made accurately and quickly; the machine must be so constructed that it can be operated by the ordinary shop mechanic; and the personal equation should be eliminated from the test.

The measurement of the penetration of a standard steel ball under a certain pressure furnishes the best method for determining hardness. The difficulty has been to construct a practical form of machine admitting of use in every-day shop practice.

The machine I will now describe was designed at the request of Mr. Vauclain, of the Baldwin Locomotive Works, for testing locomotive tires, as well as any material entering into the construction of a locomotive.

The construction of the machine is shown very clearly by Fig. 1. It consists essentially of two levers mounted on a frame and having a combined count of 100. The specimen is placed between the steel ball and the frame of the machine; the load is applied by weights at the end of one lever, which causes the steel ball at the end of the other lever to penetrate the specimen.

The penetration is measured automatically to ten-thousandths of an inch by the instrument shown on the top of the main lever.

The method used in applying the load, and a number of other details, are of special interest, and I will explain them briefly in stating the directions for making a test on the machine.

The gap for inserting the test piece is first set to suit the thickness of the specimen and the crank turned to raise the secondary lever to its highest point, thereby raising the ball and instru-

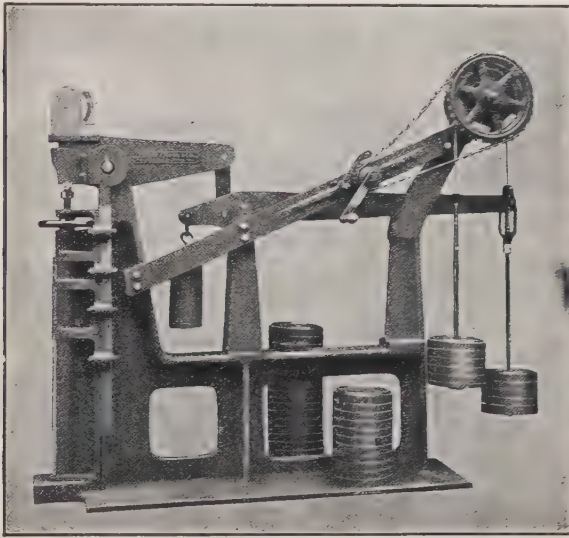


FIG. 1.—Olsen's Hardness Testing Machine.

ment within the hood shown, which protects those parts while inserting the test specimen and also acts as an abutment against which the specimen is clamped.

With the specimen in place, an initial load of 10 or 20 lbs. is applied by turning the hand crank and thus lowering the lever until it comes to rest. The pointer of the instrument is then set to zero by turning a knurled head, and the specimen is ready for testing.

A constant pressure is applied for any given material. The equivalent weights are placed on the bail suspended from the

clevis having the elongated slot in which the lever acts, and are applied to the lever by still further turning the hand crank until they are suspended from the pivot of the lever.

These weights are counterbalanced by weights on the inner bail (see Fig. 1), so that the only work the operator performs is in lifting these counterweights the length of time, a fraction of a second, required to make the penetration. A ratchet and pall hold the raised counterweights in position until the operator reads the penetration on the dial. The weights are then released, the lever raised to the top position and the specimen removed. The machine is now ready for another test. To test a specimen in this machine takes less than a minute, including the time required for inserting and removing the test piece.

The most accurate method of applying the load is by means of a balanced lever system, as it is not subjected to variation and can be verified at any time. The instrument can also be very readily calibrated, so the machine is as accurate as can be made.

To illustrate the accuracy, a piece of high-carbon steel made especially uniform by an annealing process, was tested in spots along its length, the loads varying by 500-lb. increments up to 10,000 lbs. The consequent indentations noted were very uniform. Successive increments of the 500-lb. load up to 10,000 lbs. were again applied to the same spots without disturbing the instrument or specimen, and the increments of indentation were found to be very uniform, the final indentation in each case being the same.

This machine is adapted to a large range of specimens, as over 500 degrees of hardness may be noted for each variation of load. The proper load to use for various materials, which must be governed to a certain extent by experiment, are as follows:

Babbitts	500 lbs. to	1,000 lbs.
Bronzes	2,000 "	
Cast iron	3,000 "	
Steel	5,000 "	
Special test	5,000 " "	10,000 "

The instrument is entirely encased and all small parts thoroughly protected so that no damage can occur in ordinary use.

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PAST OFFICERS.

NOTE.—The Society, from its organization in 1898 till its incorporation under its present name in 1902, was designated the American Section of the International Association for Testing Materials.

The officers and members of the Executive Committee during this four-year period were as follows:

CHAIRMEN:

MANSFIELD MERRIMAN, 1898-1900.

HENRY M. HOWE, 1900-1902

VICE-CHAIRMEN:

HENRY M. HOWE 1898-1900.

CHARLES B. DUDLEY 1900-1902.

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RICHARD L. HUMPHREY, 1898-1900.

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PAUL KREUZPOINTNER, 1898-1900.

R. W. LESLEY, 1900-1902.

MEMBERS OF EXECUTIVE COMMITTEE:

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ON TESTS AND TESTING APPARATUS.

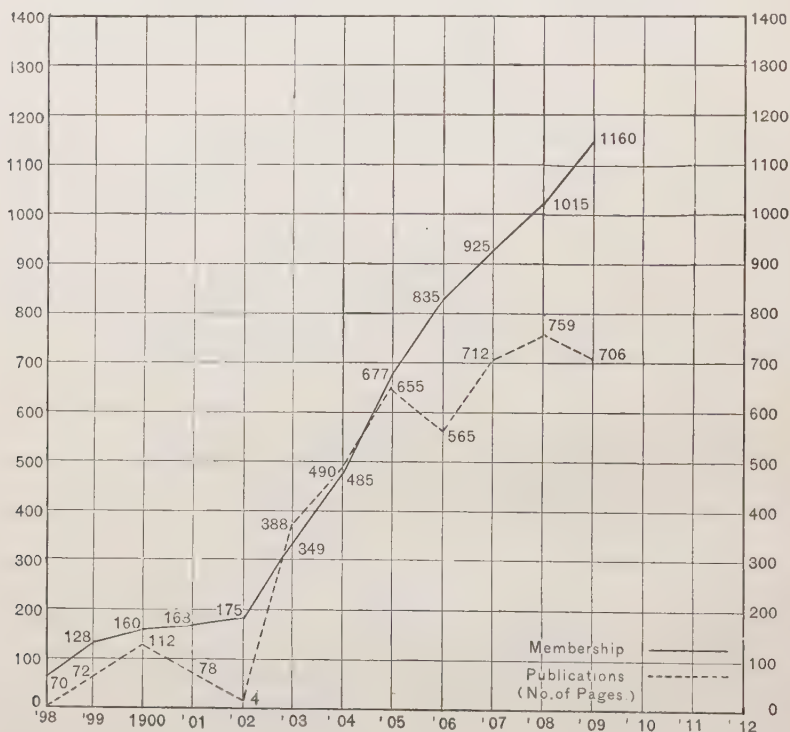
GAETANO LANZA, *Chairman.*

Mansfield Merriman,

Tinius Olsen.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

Since the Eleventh Annual Meeting of the Society, the Executive Committee has held four regular meetings, of which two were informal, owing to the absence of a quorum. An abstract of the minutes of these meetings is appended to this report.



Membership.—The membership at the last annual meeting was 1,015. Since then 216 applications for membership have been approved. The Society has suffered the loss of two members in the death of Victor S. Allien, which occurred on February 1, 1908, but was not brought to the notice of the Secretary in time for announcement in the last annual report, and that of Thomas Gray, who died on February 12, 1909. The number of resignations for

the year is 28, and 41 members have been dropped for arrears in dues. The total loss from all causes is 71, leaving a net gain of 145, and making the total membership at present 1,160. It is particularly gratifying to note that, notwithstanding the unusually heavy loss from various causes, the net increase is 60 per cent. greater than for either of the two preceding years.

Publications.—The statistical diagram embodied in this report is somewhat misleading in respect to the apparent diminution of printed matter issued during the past year as compared with previous years. By authority of the Executive Committee, the membership list and other statistical data was not reprinted in the last volume of the Proceedings (Vol. VIII, 706 pp.), as in previous years. This matter was issued, however, as usual, in the form of a separate pamphlet of 127 pp. Five official circulars of information were also issued during the year.

Technical Committees.—In pursuance, partly of action at the last annual meeting, and partly at its own initiative, the Executive Committee has created the following new technical committees:

Committee O, on Standard Specifications for Coal.

Committee V, on Standard Specifications for Cold-Drawn Steel.

Committee W, on Standard Specifications for Hard-Drawn Copper Wire.

Committee X, on Standard Methods of Analysis of Fats and Oils.

Committee Y, on Standard Tests of Insulating Materials.

Reports from Committees O, V and W are in prospect for this meeting. Committee X is cooperating with other committees on the same subject representing the American Chemical Society and the Association of Official Agricultural Chemists, and the organization of Committee Y is in progress.

Finances.—The financial condition of the Society is by no means as favorable as might be inferred from the fact that there are no unpaid bills on hand, and that the Treasurer's report shows a cash balance of \$1,217.78 on June 15, 1909, for it will also be seen from that report that the payment of dues for the fiscal year beginning July 1, 1909, has been anticipated to the extent of \$3,385.00. The prospective receipts during the ensuing fiscal year will there-

fore fall considerably short of meeting the financial requirements, and the next annual report may be expected to show a substantial deficit. The advance payment of \$3,385.00 may be regarded as equivalent to a lien to that amount on the receipts for the next fiscal year. If this condition did not exist, the Society might be expected to meet its prospective financial obligations for the coming year from its regular resources, as may be seen from the following analysis:

Membership dues, after deducting prospective delinquencies..	\$5,500.00
Membership dues, new members	600.00
Sales of publications	1,000.00
Sales of right of republishing specifications	500.00
	\$7,600.00

By the exercise of rigid economy, this sum would barely suffice to meet the requirements for the year.

To extinguish the impending deficit, which seems inevitable, three courses appear to be open: the solicitation of special subscriptions, as in the earlier days of the Society; the renewed support of the contributing members, who have not been called upon for two years, and an effort to increase their number; or, lastly, a suitable increase in membership dues. Experience has shown that, at the present membership dues, the increased cost of carrying additional members is practically as great as the increased returns from dues.

The financial situation and the best remedy for the same will receive careful consideration at the hands of the Executive Committee, in the confident expectation that whatever policy may eventually be recommended will receive the same cordial support on the part of the membership at large as in the past.

As will be seen from the report of the Treasurer, the sales of the right (not exclusive) to reprint and circulate the standard specifications of the Society for one year have yielded a return of \$500, of which sum \$250 was paid by the American Association of Portland Cement Manufacturers, and \$250 by the Carnegie Steel Company. It is hoped that its copyrighted specifications will prove an asset of progressively increasing value to the Society. A contribution of \$200 was also raised by Committee E towards the cost of publishing and reprinting its extensive report of last year. The Executive Committee found it necessary to negotiate a temporary loan of

\$1,000 during the past year to meet current obligations, which loan has been repaid in full. Arrangements have been made by which the books and accounts of the Society are rigidly audited semi-annually, from the date of the last annual report, by a firm of expert accountants.

ANNUAL REPORT OF THE TREASURER.

From June 15, 1908, to June 15, 1909.

RECEIPTS.

Membership dues to July 1, 1909.....	\$3,529 89
Membership dues, July 1, 1909, to July 1, 1910....	3,385 00
Collections for account International Association...	433 95
Sales of publications.	875 44
Sales of right to reprint specifications for one year..	500 00
Contribution from Committee E.....	200 00
Temporary loan, Manayunk National Bank.....	1,000 00
Orders for binding.....	559 15
Reprints.....	189 30
Interest on deposits.....	7 79
Miscellaneous receipts.....	8 10

Total receipts.....	\$10,688 62
Cash balance, June 15, 1908.....	285 23

\$10,973 85

DISBURSEMENTS.

Remitted to International Association, dues, etc...	\$740 43
Subscription to International Association, (100 frs.)	19 45
Printing, engraving, binding, etc.....	4,479 48
Secretary's salary, May 31, 1908, to May 31, 1909..	1,500 00
Clerical services.....	1,158 38
Accountant's audit.....	40 00
Expenses, Secretary's office.....	251 71
Repayment of temporary loan.....	1,000 00
Interest on temporary loan.....	28 33
Rent, storage room.....	131 60
Stenographer, Eleventh Annual Meeting.....	150 00
Expenses, Eleventh Annual Meeting.....	184 94
Committee expenses.....	30 01
Excess remittances refunded.....	28 74
Miscellaneous disbursements.....	13 00

Total disbursements.....	\$9,756 07
Cash balance, June 15, 1909.....	1,217 78

\$10,973 85

JOHN HEINS & Co.
Public Accountants and Auditors.

PHILADELPHIA, March 19, 1909.

To the Executive Committee of the American Society for Testing
Materials:

Dear Sirs: We respectfully report that we have made an audit and examination of the books and accounts of your Society for the six months ending December 31, 1908, and report them to be correct.

Yours respectfully,
(Signed) JOHN HEINS & Co.

Proposed Amendments of the By-Laws.—As announced in Circular No. 40, issued last April, the Executive Committee proposes the following amendments of the By-Laws:

To strike out Sec. 3, Art. V; viz.,

Any member of the Society whose dues shall remain unpaid for the period of one year shall forfeit the privileges of membership. If he neglects to pay his dues within thirty days thereafter, and after notification from the Secretary, his name may be stricken from the roll of membership by the Executive Committee,

and to substitute the following new sections:

SEC. 3. Any member of the Society whose dues shall remain unpaid for a period of three months from the beginning of the fiscal year shall receive a "Second Notice" from the Treasurer; if his dues shall remain unpaid for a period of five months from the beginning of the fiscal year, he shall forfeit the right to vote and to receive the publications of the Society. A month before the close of the fiscal year, he shall receive a final notice from the Treasurer that, if he neglects to pay his dues before the end of the fiscal year, his name may be stricken from the roll of membership by the Executive Committee.

SEC. 4. Any person elected after six months of any fiscal year shall have expired, shall pay only one-half of the amount of dues for that fiscal year; but he shall not be entitled to a copy of the Proceedings of the previous annual meeting.

SEC. 5. The resignation of a member whose dues for the current fiscal year are unpaid, shall be acceptable only if it be received within one month from the beginning of the fiscal year, unless an exception be authorized by special action of the Executive Committee.

SEC. 6. Charges for cloth and half-leather binding for the Proceedings shall be payable in advance.

Relations with the International Association for Testing Materials.—Of the 1,160 members of the American Society, only

305 hold membership in the International Association, representing an increase of 145 in the former, and 38 in the latter, for the year. The efforts of the Executive Committee to increase the American membership in the International Association have not met with the response that might reasonably have been anticipated. The total membership of the International Association, as reported at the beginning of the current year, was 1,900, distributed among 24 countries, Germany leading with 370 members and the United States following next with 293. These statistics are practically the same as those of six years ago, as given in Vol. II of the Proceedings. The total membership at that time was 1,950, the German representation 370, and the American representation 290. The independent publication of the Proceedings of the International Association in pamphlets printed in three languages, of which five numbers aggregating 175 pages have appeared since May, 1908, should serve to greatly stimulate the membership in that Association.

The Fifth International Congress will be held in Copenhagen, September 7-11, 1909. The reports and papers presented on that occasion will appear in the "Proceedings" in three languages. Members of the American Society will accordingly find membership in the International Association highly advantageous. The annual dues are \$1.50, and application blanks for membership may be obtained, on request, from the Secretary of the American Society. It is gratifying to note that contributions from seven American members are announced on the program of the Congress, and the American participation in the way of attendance also promises to be much better than at the last Congress, held at Brussels in 1906. The Executive Committee has authorized a subscription of 100 francs on the part of the American Society towards the treasury of the International Association.

Respectfully submitted on behalf of the Executive Committee,

CHARLES B. DUDLEY,
President.

EDGAR MARBURG,
Secretary-Treasurer.

APPENDIX.

ADSTRACT OF MINUTES OF THE EXECUTIVE COMMITTEE.

REGULAR MEETING, June 25, 1908.—Hotel Traymore, Atlantic City, N. J. Present: Mr. C. B. Dudley, President; Mr. R. W. Lesley, Vice-President, and Mr. Edgar Marburg, Secretary-Treasurer.

In the absence of a quorum the meeting was declared informal, with the understanding that any action taken would be subject to the approval of the Executive Committee at its next meeting.

The Secretary reported the receipt of 41 applications for membership, duly approved, 5 resignations, the dropping of 28 members, and 2 deaths: F. C. Warman, who died on April 27, 1908, and D. Woodman, who died on September 4, 1907, making the total membership on June 15, 1908, 1,015.

The Secretary submitted correspondence with the Universal Portland Cement Company, Chicago, requesting permission to reprint the standard specifications for cement. This matter was discussed in connection with the past practice of other corporations and associations in reprinting the standard specifications of the Society on an extensive scale, without any financial returns to the Society. It was agreed that the copyrighted specifications should be regarded as a valuable asset of the Society, and that its financial interests in connection with such publications should be duly safeguarded. It was accordingly decided to take this matter up with the Association of American Portland Cement Manufacturers direct.

The Secretary submitted a communication from Mr. J. A. Holmes, Chairman pro-tem. of the Committee on Standard Specifications for Coal, reporting good progress in the organization of that committee.

The Secretary presented a number of letters from the heads of various Government Bureaus interested in the testing of materials, in reply to a communication addressed to them by the President and Secretary of the Society in pursuance of action at the last quarterly meeting, inviting their cooperation with the Society on matters of mutual interest, the general tenor of these letters being favorable to the proposal.

The Secretary submitted a letter from the International Association for Testing Materials, relating to the following matters:

1. The designation by the Executive Committee of a member of the Society to report, at the next Congress, the results of the investigations made in this country, under the auspices of the American Society for Testing Materials, on Preservative Coatings.

2. An invitation for the contribution of independent papers by the American members of the International Association, on the "principal subjects" designated by the Council for discussion at the Fifth Congress.

3. The announcement of the proposed publication of an official journal by the International Association.

The financial needs of the Society, and the best means of meeting the situation, were fully discussed.

It was decided to request Committee A to consider the early revision of the standard specifications for wrought iron.

REGULAR MEETING, October 5, 1908.—Engineers' Club of Philadelphia, Philadelphia, Pa. Present: Mr. C. B. Dudley, President; Mr. R. W. Lesley, Vice-President; Mr. W. A. Bostwick and Mr. William R. Webster, members of the Executive Committee, and Mr. Edgar Marburg, Secretary-Treasurer.

On motion, the action taken at the previous meeting, in the absence of a quorum, was approved.

The Secretary reported the receipt of 67 applications for membership, duly approved, the resignation of 2 members, and the death of V. S. Allien, which occurred on February 1, 1908, making the total membership 1,079.

The Treasurer called attention to the deficit of \$123.74, incurred at the annual meeting in connection with the smoker and dinner, and it was decided that the same should be assumed by the Society.

The Treasurer reported that for the temporary relief of the financial situation, a loan of \$1,000.00, with interest at 6 per cent. per annum, had been negotiated with the Manayunk National Bank on a note bearing the indorsements of Mr. R. W. Lesley, Mr. James Christie and himself; that the outstanding bills aggregated \$607.88 and the outstanding accounts collectable were estimated at about \$1,000.00; and that the regular receipts of the Society were not yet quite sufficient to meet expenses.

It was the sense of the meeting that the membership dues should not be raised until other expedients for increasing the revenue of the Society had been exhausted. Among the latter, an effort to extend the list of contributing members was considered. The Secretary reported that the present contributing members had not been called upon for contributions during the present and preceding fiscal years. It was decided, before such action should be taken, to consider the possibility of raising revenue from organizations and firms desiring to reprint and circulate the standard specifications on a large scale. The Secretary submitted correspondence in that connection with various corporations and individuals, which led to the following action:

1. That authority to reprint the specifications be accorded, without compensation to the Society, to authors of books desiring to quote these specifications, and to consumers who desire to adopt the same in connection with the purchase of materials.

2. That individual manufacturers or manufacturers' associations, desiring to reprint the copyrighted standard specifications of the Society,

should be permitted to do so only on the payment of an annual charge, to be fixed according to circumstances.

3. That an annual charge of \$250.00 be made to the Association of American Portland Cement Manufacturers for the privilege of reprinting and circulating the standard specifications for cement, and that a like charge be made to the Carnegie Steel Company for like privileges in connection with the standard specifications for steel.

The Secretary reported that the effort to extend the American membership in the International Association, by calling attention, in the last circulars to members, to the Congress of 1909 and the advantages of membership, had been disappointing, the membership having been increased by the number of only 14.

The Secretary reported that in pursuance of an invitation from the International Council, President Dudley had nominated Mr. A. N. Talbot for the Vice-chairmanship of the International Committee on Reinforced Concrete, and Mr. F. E. Turneaure to membership on that Committee, and that both nominees had accepted.

In reply to the invitation for the nomination of an American member on the International Committee on the Magnetic Testing of Materials, it was decided to nominate Mr. J. W. Esterline.

The Secretary reported that Mr. S. S. Voorhees had accepted the invitation to report on the work of Committee E on Preservative Coatings at the next Congress.

The Secretary's recommendation that the reprinting of the charter, by-laws, list of members, etc., in the annual volumes be discontinued, at a saving of \$150.00 to \$200.00, was approved.

After careful consideration, it was decided that no steps should be taken at present towards the publication of the standard specifications in the form of a separate volume.

The Secretary submitted a recommendation for the creation of a committee on standard specifications for cold-drawn steel, on which favorable action was taken.

It was decided to invite Professor H. M. Howe, Past President of the Society, to act as one of the representatives of the Society at the next International Congress.

The Secretary-Treasurer was authorized, in sending out bills for dues at the end of the year, to request that members who find it convenient to do so remit dues for a year and a half, instead of for six months, in order to tide over the temporary loss to the treasury incident to the change in the beginning of the fiscal year from January 1 to July 1.

REGULAR MEETING, January 4, 1909.—Engineers' Club of Philadelphia, Philadelphia, Pa. Present: Mr. James Christie and Mr. William R. Webster, members of the Executive Committee, and Mr. Edgar Marburg, Secretary-Treasurer.

In the absence of a quorum the meeting was declared informal, with

the understanding that any action taken would be subject to the approval of the Executive Committee at its next meeting.

The Secretary reported the receipt of 42 applications for membership, duly approved, and the resignation of 3 members, making the total membership 1,118.

The Secretary reported that 97 members were delinquent for 1908 dues, and he was instructed to send copies of Volume VIII of the Proceedings to delinquents only after the payment of their dues.

The Secretary announced progress in the organizations of the committees on standard specifications for coal and on standard specifications for cold-drawn steel.

It was decided to authorize the creation of a committee on standard specifications for hard-drawn copper wire.

The Secretary submitted a communication from the Chief of the Food Inspection Laboratory, U. S. Bureau of Chemistry, suggesting cooperation on the part of the Society in the standardization of methods of analysis of fats and oils. On motion, it was decided to refer this recommendation, with power, to President Dudley.

The Secretary announced a number of proposed contributions to the next International Congress on the part of the American members.

REGULAR MEETING, April 12, 1909.—Engineers' Club of Philadelphia, Philadelphia, Pa. Present: Mr. Charles B. Dudley, President; Mr. James Christie and Mr. William R. Webster, members of the Executive Committee, and Mr. Edgar Marburg, Secretary-Treasurer.

On motion, the action taken at the previous meeting, in the absence of a quorum, was approved.

The Secretary reported the receipt of 53 applications for membership, duly approved, 23 resignations, and the death of Thomas Gray, which occurred on February 12, 1909, making the total membership 1,147.

The Secretary reported that 53 members were still in arrears for 1908 dues, and he was instructed to advise these members that unless their remittances were received within ten days from date, their names would be dropped from the membership roll.

The Secretary presented a report from John Heins & Co., Public Accountants and Auditors, covering the audit of the books and accounts of the Society for the six months ending December 31, 1908, to the effect that they found the same correct.

The Secretary was authorized to make a permanent arrangement with John Heins & Co. to audit the books and accounts at intervals of six months, at a charge of \$40.00 for each audit.

The Secretary reported the organization of the following committees:

- O. On Standard Specifications for Coal.
- V. On Standard Specifications for Cold-Drawn Steel.
- W. On Standard Specifications for Hard-Drawn Copper Wire.
- X. On Standard Methods of Analysis of Fats and Oils.

The President submitted a communication from an officer of the U. S. Bureau of Standards, suggesting the cooperation of the Society with the Bureau of Standards in connection with the collection of material for "standard samples." The President was requested to communicate with the Bureau of Standards, with the view of ascertaining whether the Bureau would be prepared to defray the expenses of such a committee, and to state that the question would be presented for discussion at the next annual meeting of the Society.

It was decided to authorize an annual subscription of 100 francs on the part of the Society to the general funds of the International Association.

The Secretary was authorized to expend an amount, not exceeding \$300.00 within one year, for extra clerical services, at a compensation of 37½ cents per hour.

It was decided to propose the following amendments to the By-Laws:

To strike out Sec. 3, Art. V; viz.,

Any member of the Society whose dues shall remain unpaid for the period of one year shall forfeit the privileges of membership. If he neglects to pay his dues within thirty days thereafter, and after notification from the Secretary, his name may be stricken from the roll of membership by the Executive Committee,

and to substitute the following new sections:

SEC. 3. Any member of the Society whose dues shall remain unpaid for a period of three months from the beginning of the fiscal year shall receive a "Second Notice" from the Treasurer; if his dues shall remain unpaid for a period of five months from the beginning of the fiscal year, he shall forfeit the right to vote and to receive the publications of the Society. A month before the close of the fiscal year, he shall receive a final notice from the Treasurer that, if he neglects to pay his dues before the end of the fiscal year, his name may be stricken from the roll of membership by the Executive Committee.

SEC. 4. Any person elected after six months of any fiscal year shall have expired, shall pay only one-half of the amount of dues for that fiscal year; but he shall not be entitled to a copy of the Proceedings of the previous annual meeting.

SEC. 5. The resignation of a member whose dues for the current fiscal year are unpaid, shall be acceptable only if it be received within one month from the beginning of the fiscal year, unless an exception be authorized by special action of the Executive Committee.

SEC. 6. Charges for cloth and half-leather binding for the Proceedings shall be payable in advance.

Favorable action was taken on the proposal for the creation of a committee on standard tests of insulating materials.

The Secretary's recommendation that he be authorized to print committee reports and papers, in so far as possible, in advance of the approaching annual meeting, was approved.

STANDARD SPECIFICATIONS

ADOPTED BY THE

AMERICAN SOCIETY FOR TESTING MATERIALS.

NOTE.—The formulation and adoption of Standard Specifications for the various materials of engineering is one of the important functions of the Society. These specifications are revised from time to time to meet changed conditions.

The following complete list of Standard Specifications, in their latest revised form, is here given for convenience of reference:

1. Standard Specifications for Structural Steel for Bridges, (1909), Vol. IX, pp. 37-41.
2. Standard Specifications for Structural Steel for Buildings, (1909), Vol. IX, pp. 47-50.
3. Standard Specifications for Structural Steel for Ships, (1909), Vol. IX, pp. 42-46.
4. Standard Specifications for Open-Hearth Boiler Plate and Rivet Steel, (1909), Vol. IX, pp. 51-55.
5. Standard Specifications for Bessemer Steel Rails, (1909), Vol. IX, pp. 62-65.
6. Standard Specifications for Open-Hearth Steel Rails, (1909), Vol. IX, pp. 66-69.
7. Standard Specifications for Steel Splice Bars, (1909), Vol. IX, pp. 56-57.
8. Standard Specifications for Steel Forgings, (1905), Vol. V, pp. 59-62.
9. Standard Specifications for Steel Axles, (1905), Vol. V, pp. 56-58.
10. Standard Specifications for Steel Tires, (1909), Vol. IX, pp. 58-61.
11. Standard Specifications for Wrought Iron, (1901), Vol. I, pp. 231-236, Bulletin No. 24.
12. Standard Specifications for Steel Castings, (1905), Vol. V, pp. 53-55.

13. Standard Specifications for Malleable Castings, (1904), Vol. IV, pp. 95-96.
14. Standard Specifications for Foundry Pig Iron, (1909), Vol. IX, pp. 111-113.
15. Standard Specifications for Cast Iron Pipe and Special Castings, (1904), Vol. IV, pp. 57-66.
16. Standard Specifications for Locomotive Cylinders, (1904), Vol. IV, pp. 69-70.
17. Standard Specifications for Cast Iron Car Wheels, (1905), Vol. V, pp. 65-70.
18. Standard Specifications for Gray Iron Castings, (1905), Vol. V, pp. 71-74.
19. Standard Specifications for Hard-Drawn Copper Wire, (1909), Vol. IX, pp. 311-318.
20. Standard Specifications for Cement, (1909), Vol. IX, pp. 116-130.
21. Standard Test for Fireproof Floor Construction, (1908), Vol. VIII, pp. 210-212.
22. Standard Test for Fireproof Partition Construction, (1909), Vol. IX, pp. 281-282.
23. Standard Abrasion Test for Road Material, and Standard Test for Macadam Rock, (1908), Vol. VIII, pp. 197-200.
24. Standard Specifications for Structural Timber, (1907), Vol. VII, pp. 187-192.

The price of the above standard specifications is 25 cents each, or 15 cents each in lots of ten or more. The price of the complete set of twenty-four specifications is \$3.00.

Members of the Society may obtain the above standard specifications at the following special prices: Single copies, 15 cents; in lots of ten or more, 10 cents each; complete set, \$2.00.

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